Cogen INDIA '96

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The First International Cogeneration Conference in India

Hotel Taj Palace Intercontinental, New Delhi
10–12 March 1996

teri

Tata Energy Research Institute

Conference Schedule

10 March 1996

SESSION I INAUGURAL SESSION (5:00 pm)
(Shahjehan Hall)

5:00 pm	*Welcome Address* **Dr R K Pachauri** Director, TERI *Cogeneration Potential in India—An Overview* **Mr Pradeep Dadhich** Fellow, TERI **Mr R V Ramani** Director, Thermax Ltd *Inaugural Address* **Mr N K P Salve** Hon'ble Minister for Power, Government of India *Presidential Address* **Prof. P J Kurien** Hon'ble Minister for Non-conventional Energy Sources, Government of India *Vote of Thanks* **Dr Leena Srivastava** Dean, TERI
6:00 pm	*Inauguration of Exhibition*
6:30 pm	*Reception*

11 March 1996

8:30–9:30 am	*Registration*	Shahjehan Hall

SESSION II REGULATORY AND POLICY ISSUES (9:30–10:45 am)
(Shahjehan Hall)

Panel Chairman	*Mr P Sengupta*	*Advisor, Planning Commission*
Panel Co-Chairman	*Mr V Raghuraman*	*Secretary General*, ASSOCHAM

• Government of India's policies on cogeneration/ independent power producers	**Mr Pradip Baijal** Joint Secretary, Ministry of Power Government of India
• Government of India's policies on biomass/bagasse-based cogeneration	**Mr Sudhir Mohan** Director (Cogen) Ministry of Non-conventional Energy Sources, Government of India
• Pricing policy for cogeneration: issues and options	**Mr Sanjeev Ahluwalia** Fellow, TERI
• Regulatory issues regarding pricing policy, wheeling and banking charges for cogen power	**Mr S K Mukherjee** **Mr Pradeep Dadhich** TERI

Question–Answer Session

Tea/coffee break 10:45–11:15 am

SESSION III FINANCIAL AND CONTRACTUAL ISSUES (11:15–12:45 pm)

(Shahjehan Hall)

Panel Chairman *To be confirmed*

• Indian financing options for biomass-based cogeneration	**Dr B S K Naidu** General Manager (Power) Indian Renewable Energy Development Agency (IREDA)
• Financial structure for cogeneration projects	**Ms K Sudha, Mr Rajeev Suri** Kotak Mahindra Finance Ltd.
• Contractual issues concerning cogeneration	**Mr Dan Jantzen** Asia Projects Manager Winrock International, USA
• Independent project developer views on contractual issues concerning cogeneration with specific reference to India	**Mr Gregory N Ullman** Partner, Chadbourne & Parke Associates
• Cogeneration in sugar mills: some technical and commercial issues	**Mr Harish Bhargava** Associate Consultant MITCON Ltd

Question–Answer Session

Conference lunch hosted by
Infrastructural Leasing and Financial Services Ltd (IL & FS) 12:45–2:15 pm

and

Special presentation on 'Cogeneration of Power' IL & FS

Special Session Cogeneration and environment (2:15–3:15 pm)

Panel Chairman	*Mr Vijay Sharma*	*Joint Secretary* *Ministry of Environment and Forests, Government of India*

- Environmental benefits of cogeneration
- International Financing Mechanisms (GEF) and Cogeneration
- Policies of USIJI

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Tea/coffee break 3:15–3:45 pm

SESSION IV COGENERATION TECHNOLOGIES (3:45–5:30 pm)

Parallel Session IV A Gas and steam turbines and boilers
(Shahjehan Hall)

Panel Chairman	*Mr A Subramanian*	*Executive Director (IS)* *Bharat Heavy Electricals Ltd (BHEL)*

- Steam turbine options for optimizing cogeneration applications
- Gas turbines burning naphtha—special features
- Innovative cogeneration schemes for fertilizer, refinery, and process plants

Mr C N Nath
Senior Manager (Turbine Designs)
BHEL
Mr Satish Pandey
Triveni Engineering Works Ltd
Mr S Krishnan
Mr A S Belagali
Larsen & Toubro Ltd (L & T)

- High pressure boilers for cogeneration using fossil fuel — **Mr R Kamraj, Mr T Balakrishnan**, **Mr B Shanmugam**, BHEL
- Tempest turbines—a new force of nature — **Mr Rod Oglesby**, Business Development Manager, European Gas Turbines Ltd, UK

Question–Answer Session

Parallel Session IV B Small cogen systems based on renewables (Mumtaz Mahal Hall)

Panel Chairman *Mr R V Ramani* *Director, Thermax Ltd*

- High pressure boilers—design, selection, and operation — **Mr A H Mokashi**, Thermax Babcock and Wilcox Ltd
- Steam turbine applications for cogeneration — **Mr A K Srivastava**, Technical Manager, GEC Alsthom Triveni Ltd
- Biogas generation as a fuel for cogeneration — **Dr M C Bardiya**, Assistant General Manager, Daurala Sugar Works
- Utilization of sewage gas for cogeneration applications — **Dr P K Jha**, Director, Sulabh International Institute of Technical Research and Training
- Tea industry: technical options for combined heat and power (CHP) systems — **Mr Sanjay Mande, Dr V V N Kishore**, TERI

Question–Answer Session

12 March 1996

SESSION V INDIAN EXPERIENCES IN COGENERATION (9:30–11:15 am)

Parallel Session V A Industrial cogeneration systems (Shahjehan Hall)

Panel Chairman *Mr Ranjit Chakravarty* *Executive Director (Power & Energy), SAIL*

• Cogeneration power plant set up for the chemical complex at Mithapur	**Mr V P Pahuja** President, Tata Chemicals Ltd
• Cogeneration at JK paper mills	**Mr B T Sridharan** President (Paper) JK Corporation Ltd
• Waste heat recovery from flue gases with substantial dust load	**Dr J M Chawla** President CALDYN Inc., USA
• Power generation possibilities using corex technology	**Dr S K Gupta** President and Joint Managing Director Jindal Vijayanagar Steels Ltd
• Cogeneration from waste gases emanating from kilns	**Mr V P Agarwal** (Managing Director) **Mr K C Sood** (President) Prakash Industries Ltd
• Cogen experiences at IPCL	Mr B P Mardia Senior Manager Indian Petrochemicals Ltd (IPCL)

Question–Answer Session

Parallel Session V B Bagasse-based cogen systems
(Mumtaz Mahal Hall)

Panel Chairman *Mr Ram V Tyagarajan* *Chairman and Managing Director*
Thiru Arooran Sugar Mills Ltd
Madras

• Evaluation of 20 MW bagasse-based cogen power—a case-study	**Mr M S Bhalla, Mr H S Nagi** TERI
• High pressure boilers for bagasse-based cogeneration at EID Parry (I) Ltd	**Mr C V Krishnan** President (Sugar), **Mr P Ram Babu** Vice President (Sugar) EID Parry (India) Ltd
• Industrial negotiating with regard to setting up of cogeneration plant—Simbhaoli experience	**Mr Satwant Singh** Executive Director The Simbhaoli Mills Ltd
• Wheeling of power to industrial customers in Karnataka	**Mr S Chandrashekhar** Executive Director Bhorukha Power Corporation
• Bagasse-based cogeneration options in the Indian sugar industry	**Mr G C Dutta Roy** Director (Technology) Turner Morrison Group

- Biomass energy systems — **Ms Sangeeta Wij**
  Programme Manager (GEP)
  USAID

Question–Answer Session

Tea/coffee break 11:15–11:45 am

SESSION VI PLENARY SESSION ON INTERNATIONAL EXPERIENCES IN COGENERATION (11:45 am–1:45 pm)

Panel Chairman	*Mr Ajit Gupta*	*Advisor, Ministry of Non-conventional Energy Sources*
Panel Co-Chairman	*Mr Satwant Singh*	*Executive Director The Simbhaoli Sugar Mills Ltd*

- Cogenerated power regulations and tariffs in France — **Mr Jean-Pierre Tabet**
  ADEME, France
- Gas turbine systems development to meet the requirements of dual fuel biomass/diesel oil applications — **Mr T I Mina**
  European Gas Turbine, UK
- Netherland's experience on biomass-based cogeneration — **Dr Ir. Hubert E Stassen**
  Director, Biomass Technology Group BV, University of Twente
  The Netherlands
- Danish energy policy with focus on cogeneration on straw and grid connection from small cogeneration plants — **Mr Lars Nikolaisen**
  Danish Technological Institute
  Denmark
- Continuing story of CHP in the Netherlands — **Mr Kornelis Blok, Mr Jacco Farla**
  Mr Lars Hein
  Department of Science
  Technology and Society
  Utrecht University, The Netherlands
- Technologies in small cogeneration systems based on biomass fuels in the ASEAN region — **Dr S Sasmojo**
  Head, Center for Research on Energy
  Indonesia
- International experiences in bagasse-based cogeneration — **Mr Dan Jantzen**
  Asia Projects Manager
  Winrock International, USA

	• Combustion of low heating value gas in a gas turbine	**Mr T I Mina** European Gas Turbine, UK
	• Combined heat and power in the IEA member countries	**Mr John Newman** International Energy Agency (IEA) France

Question–Answer Session

Conference Lunch 1:45–2:45 pm

2:45–3:30 pm	Discussion on the relevance of international experiences in the Indian context	**Mr Dan Jantzen** Asia Projects Manager Winrock International, USA **Mr Ajit Gupta** Advisor, MNES **Mr R Kanan** Deputy Zonal Manager ICICI Ltd **Mr V K Goel** Chairman Dhampur Sugar Mills Ltd

Tea/coffee break 3:30–4:00 pm

CONCLUDING SESSION 4:00–5:00 pm

(Shahjehan Hall)

Final Panel Discussion

Cogen INDIA '96

The First
International Cogeneration Conference in India
March 10-12, 1996, Hotel Taj Palace Inter-Continental
New Delhi, India

INFORMATION FOR DELEGATES

Welcome to the "First International Cogeneration Conference in India"

This folder contains some important information.

Participants are advised to take full advantage of the time allocated for questions and discussions at the end of each session. There are question sheets provided in the folder for your convenience. Additionally, the refreshment breaks will allow an opportunity to meet and interact with other delegates.

The following information will be useful:

Conference Badges	For security reasons you must be registered and issued with a name tag. There will be no entry to the Conference and Exhibition area for people not wearing Cogen INDIA '96 Badges.
Pre-registration time	8.30 am to 9.30 am on March 11, 1996 at the Shahjehan Hall Foyer, Taj Palace Inter-Continental Hotel.
Conference Sessions	The sessions will be held in the Mumtaz and Shahjehan Hall.
Cogen India '96 Exhibition	The Exhibition will be held in the Exhibition Hall from March 10 to 12 1996.
Lunches	The lunch on March 11, 1996 will be hosted by IL & FS.
Messages	Please check the Message Board (located at the Shahjehan Hall Foyer) during breaks for any incoming messages.

TERI and the hotel representatives will be on hand to assist you at all times.

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TECHNOLOGY. PROJECTS. INVESTMENT BANKING.
A WHOLE NEW SCHOOL OF THOUGHT.

A BRIEF OVERVIEW

Infrastructure Leasing and Financial Services (IL&FS) is an uniquely positioned organisation providing innovative services in its mandated areas of operation since 1988. It was set up as a joint venture between Central bank of India, Unit Trust of India and Housing Development Financial Corporation Limited. To enhance its comparative advantage through international partnership and to broad base shareholdings, IL&FS included Orix Corporation of Japan, one of the world's largest financial services companies and International Finance Corporation, Washington D.C. as shareholders.

Its objective encompasses implementing infrastructure projects on a commerical format and provision of a wide range of financial services to the Corporate sector and the Government. IL&FS has established a consistent track record in meeting its financial targets with a steady growth rate in profits since its inception. It is the only institution in India to actively pursue the implementation of infrastructure projects across diverse sectors, where it helps conceptualise the project, access appropriate technology, develop legal and financial framework, structure the financing and, if required, assist in project management and implementation. More importantly, it has accessed international technology, persuaded collaboration to domicile locally and in certain projects participate in project risks.

IL&FS has established for itself a reputation as a player that delivers value addition and quality, in its mandated areas of operation, which can be segmented into five broad areas:

(1) The Commercialisation of Infrastructure Projects

- (a) Surface Transport
- (b) Transportation Systems
- (c) Transportation Infrastructure
- (d) Integrated Area Development
- (e) Water Supply
- (f) Power
- (g) Telecommunications

(2) Investment Banking:

- (a) Asset Finance
- (b) Structured Finance
- (c) Corporate Advisory Services
- (d) Project Finance
- (e) Capital Market

(3) Securities Management including:

- (a) Agency Broking and Trading
- (b) Distribution

(4) Management of Mutual Funds

(5) Extension of Venture Capital

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ENERGYWORKS

EnergyWorks is a new joint venture between PacifiCorp and Bechtel created to develop small power projects throughout the world employing clean energy technologies. PacifiCorp is a large U.S. utility and Bechtel is a large international engineering and construction firm. Initial operations for EnergyWorks will be in India, Indonesia, and Latin-America. In those locations, customers to be served include gird-connected utilities supplied with renewable energy based power and industries where captive power, cogeneration and energy efficiency services will be provided. Finally, rural. dispersed customers complete the picture of markets served where small, modularized, renewable energy systems are the most cost competitive.

EnergyWorks is aiming to become the world leader in small power project development by combining the roles of developer, investor, EPC contractor, and on-going owner/operator. In the industrial sector we offer to jointly develop with the facility captive power and cogeneration projects as well as energy efficiency services utilizing a performance contracting approach. In this field, EnergyWorks will provide:

- Preliminary project assessment
- Joint venture establishment - agreement preparation and legal registration
- Fuel supply agreement preparation and negotiation
- Power purchase contract preparation negotiation
- Engineering, procurement and construction management
- Financing and equity investment
- Plant operation and maintenance

Mission Statement

To be a world leader in the commercial application of small, modular, and dispersed energy systems and energy efficiency services which meet the growing global need for energy technologies that sustain economic development and preserve the environment.

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KIRLOSKAR GROUP

STARTED IN 1888 WITH AN IRON PLOUGH.

TODAY, WE FOCUS ON THE FOLLOWING BUSINESSES:
- PRIME MOVERS AND TRANSMISSION
- ELECTRICAL POWER EQUIPMENT
- METAL PROCESSING
- METAL CUTTING MACHINERY
- FLUID HANDLING AND COMPRESSION
- PROJECTS AND SYSTEMS ENGINEERING
- SERVICES

YEAR OF INCORPORATION	:	1888
TOTAL SALES TURNOVER	:	RS.20,000 MILLION
(YEAR ENDING MARCH 1995)	:	US$ 700 MILLION (APPROX.)
TOTAL EMPLOYMENT	:	23000

CORE COMPANIES AND PRODUCTS

KIRLOSKAR BROTHERS	:	PUMPS, VALVES, MACHINE TOOLS
MYSORE KIRLOSKAR	:	MACHINE TOOLS, MACHINING CENTERS CASTINGS, BEARINGS.
KIRLOSKAR OIL ENGINES	:	DIESELENGINES,BEARINGS,ENGINE VALVES GENERATING SETS, GAS & STEAM TURBINES.
KIRLOSKAR ELECTRIC	:	AC MOTORS, GENERATORS, TRANSFORMERS INDUSTRIAL ELECTRONICS, PROJECT & SYSTEMS.
KIRLOSKAR PNEUMATIC	:	COMPRESSORS, REFRIGERATION AND AIR CONDITIONING SYSTEMS, POWER TRANSFORMERS.

OTHER KIRLOSKAR GROUP COMPANIES

- KIRLOSKAR FERROUS INDUSTRIES LIMITED
- KIRLOSKAR ELECTRODYNE LIMITED
- KIRLOSKAR COMPUTER SERVICES LIMITED
- KIRLOSKAR SYSTEMS LIMITED
- KIRLOSKAR WARNER SWASSEY LIMITED
- KIRLOSKAR AAF LIMITED
- KIRLOSKAR EBARA PUMPS LIMITED

- KIRLOSKAR COPELAND LIMITED
- GG DANDEKAR MACHINE WORKS
- SHIVAJI WORKS LIMITED
- KIRLOSKAR INVESTMENTS & FINANCE LIMITED

THE KIRLOSKAR GROUP ADVANTAGE

- PREMIER ENGINEERING GROUP, SERVING ALL SEGMENT OF ECONOMY OVER A CENTURY.
- HIGH LEVEL SYNERGY IN GROUP COMPANIES.
- MULTI PRODUCT GROUP TO PROVIDE TOTAL ENGINEERING SOLUTIONS.
- GROUP COMPANY PRODUCTS USED IN AGRICULTURE, INDUSTRIES, POWER, MINING & TRANSPORTATION INCLUDING RAILWAYS AND DEFENSE SECTOR.
- RECENT ENTRY INTO NON-CONVENTIONAL ENERGY SECTOR
    - WIND
    - SOLAR
    - MINI-HYDRO

THE KIRLOSKAR GROUP ADVANTAGE

- TQM CULTURE ADAPTED IN ALL GROUP COMPANIES.
- ALL MAJOR GROUP COMPANIES HAVE BEEN AWARDED ISO:9001 CERTIFICATES.
- SUBSTANTIAL R&D FACILITIES TO TAKE UP DEVELOPMENT PROGRAMMES.
- SELECT TECHNOLOGY SOURCING FROM WORLD LEADERS.
- JOINT VENTURES WITH REPUTED CORPORATIONS.
    - COPELAND, USA
    - EBARA PUMPS, JAPAN
    - AMERICAN AIR FILTER, USA
    - WARNER SWASSEY, USA
    - TOYODA, JAPAN

KIRLOSKAR: *BUSINESS ETHICS & VALUES*

- CUSTOMER VALUE ENHANCEMENT
- FAIRNESS IN BUSINESS DEALINGS
- QUALITY - A LIFE TIME COMMITMENT
- BUSINESS LEVERAGE THROUGH TECHNOLOGICAL LEADERSHIP
- FAIR RETURNS FOR OUR GROWTH AND WEALTH
- MAXIMIZATION OF STAKE HOLDERS' VALUE
- HUMAN RESOURCES, OUR VALUABLE ASSET

CETHAR VESSELS LIMITED

COMPANY PROFILE

CETHAR VESSELS LIMITED was incorporated in the year 1981 as a Private Limited Company. Subsequently, it became deemed Public Limited in the year 1983 by virtue of the participation of IDBI in the equity. The present share capital of the company is 19 million rupees and net worth was around 50 million rupees as on 31.03.95. The company established its manufacturing facilities in the year of 1984 with a view to catering the requirements of Pressure Vessels, Heat Exchangers, Burner components for BHARAT HEAVY ELECTRICALS LIMITED, a dominant power plant manufacturer in the country.

However, the dream of self-sufficiency in energy was burning fiercely in the mind of CETHAR. As a result, the technology of Fluidised Bed Combustion - a process of heat generation that not only provides the most efficient combustion of variety of fuels from lowest grade coal to agrowaste, lignite etc. was picked up and diversified into the field of ATMOSPHERIC FLUIDISED BED COMBUSTION BOILERS in the year 1985. The first boiler supplied by CETHAR was commissioned on 25.12.1985. Today, there are 350 boilers in operation and another 160 boilers are in various stages of execution.

In 1994, to meet the demanding changes in the market where the trend is towards the recovery than destruction whether it is Solid Waste or Waste Heat, the company entered into a collaboration agreement with KVAERNER ENVIROPOWER of SWEDEN for CIRCULATING FLUIDISED BED COMBUSTION BOILERS and with ABCO INDUSTRIES, USA for WASTE HEAT RECOVERY SYSTEM.

The company has a marketing and AFTER SALES SERVICE network in all major cities of the country.

COGENERATION - ARE WE MISSING OUT ON AN OPPORTUNITY ?

MR R V RAMANI
THERMAX LIMITED

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

COGENERATION - ARE WE MISSING OUT ON AN OPPORTUNITY?

Gentlemen,

I. INTRODUCTION

1. Thank you very much for inviting me to participate in your seminar on Cogeneration 1996 organized by Tata Energy Research Institute. I want to compliment Dr. R. K. Pachauri and his team for initiating this two day program on Cogeneration. Nothing could have been more timely and appropriate in the context of the "power struggle" that the country is going through - and worse, the future looks even more bleak.

2. In a paper presented by Mr. R. D. Aga, the late Chairman and Managing Director of my company, way back in October 1993 at a seminar in Washington, he brought out some very thought-provoking points. AS a prelude to my presentation

am taking the liberty of quoting a particularly thought-provoking para from Mr. Aga's paper.

> "Dr. David Jhirad of the USAID talks of the triple bind in which a number of developed countries, including India, are caught : The lack of funds to generate, transmit and distribute electrical power to serve the needs of a growing economy; the deteriorating performance, financial and technical, of the existing utility companies, which have to generate funds for growth; and the environmental pollution of air and water to which fossil fuel combustion is a major contributor."

3. We see a flurry of activity on the power front in the country today, but in real tangible terms, the results are dismal :

   - Over 250 MOU's signed, but very few reaching even the stage of financial closure;
   - Heated debates about competitive bidding versus non-competitive bidding, again with no tangible direction or results;

- Should wheeling and banking be allowed or not;
- What kind of fuel policy liquid or otherwise do we need to have; and so on and so forth.

4. In all this maze of issues and counter issues, we seem to be missing on a vital opportunity are called DECENTRALISED POWER generation.

5. And this is where Cogeneration offer a hands down winning, viable and least cost option.

II. DECENTRALIZED POWER VERSUS CENTRALIZED POWER GENERATION

1. For decades the Indian power scenario has been dominated by large centralized utility plants spread across the country and by and large operated by state or national electricity boards. This was relevant in the past and will have relevance in the future as well.

   However, given the fact that such State Electricity Boards are strapped for funds, new private utility (centralised) power

generation projects are not taking off the ground the way we would have liked them to, MOUs for small IPPs continue to remain on paper, the rapid supply demand gap created by the growing industrialisation , etc...., it is quite clear that large capacity addition in the short run is not going to take place and therefore may not be a solution in the near and medium future.

2. So What is the solution ?

3. Clearly a shift in focus is needed from centralized to de-centralized power generation. Why ? Decentralised inside the fence power generation is very simply is cost effective, short gestation, fundable and most importanly hasle free!

4. Decentralized Power has been patronized by industry for some time now but the approach has been of a "REACTIVE" nature. It has not been thought through approach and therefore, while it answers the problem of power availability, it is many a times not the least cost option.

5. It is in this context that COGENERATION clearly stands out as a viable solution for decentralized (inside the fence) power generation not only because it effectively addresses the power problem but also because it is a <u>real</u> least cost and <u>real</u> fast track option.

III. DECENTRALIZED POWER - THE COGEN ROUTE.

1. By definition, Cogeneration is the simultaneous generation of Electrical & Thermal Energy (normally steam). The idea is simple :

- Conventional utility power plants utilize the high end potential Energy of a Combustion Process to generate Power. A good part of the low end residual energy is wasted by rejection to the atmosphere.

- On the other hand, a Cogen process, in addition to putting the high end potential Energy to use for power generation, capitalizes on the low end residual energy to work for heating processes, equipment, space or similar.

- Now, given a typical 40 : 60 ratio of the high end to low end energy, it clearly stands out that Cogeneration will substantially boost energy utilization by as much as 80- to 100% compared to a conventional power generation process because it puts to use a good part of the low end energy.

2. Almost without exception 60-65% of industries in India, need both Electrical and Thermal Energy. Today, these industries either buy their power from the State Electricity Boards (SEBs) or generate their own power (largely through Diesel Generators) and meet their Thermal Energy demands through captive boilers or other heating equipment. In other words, Electrical and Thermal energies are "Independently Generated" - they are not "Cogenerated". This fact in itself makes almost every industrial plant a potential candidate for Cogeneration and, therefore, offers a virtually unlimited market potential.

3. Indian Industry consumes Electrical Energy at different potential levels through an in-house distribution system. Thermal energy, on the other hand, is required not only at different potential levels (pressure/temperature) but also in different forms (steam, hot water, hot air, hot thermal oil and so on). This wide spectrum of thermal energy demand offers

an excellent opportunity to achieve high levels of "Cogeneration Efficiency" leaving practically very little by way of waste to the atmosphere.

4. As a tropical country (peak summer temp : 45 °C+ and country average : 33 °C+) air conditioning in India is a basic need for the comfort of man (and machine?). Until a few years ago, air conditioning chillers in India were, largely Electrically driven. Given the growing power problem in India, users of air conditioning machines were forced to either switch off such air-conditioning facilities OR operate them by installing high cost Captive Diesel Generators. Fortunately, with the revival of Absorption Cooling Systems (which run on heat instead of Electricity) in India, the dependence on power for air conditioning (or industrial process cooling) is being substantially overcome by a number of industries. This technology shift is motivating many industries to go in for air conditioning and process cooling even for applications which were earlier run without an air-conditioning or cooling facility to improve Quality and Productivity (like for eg. cotton yarn spinning). The significant factor here is that Absorption Cooling Systems come very handy as a major steam host to achieve a finely balanced and Efficient Cogen System.

A related point : Ironically, in a tropical country like India, for over four decades, Air conditioning has been classified by the

Indian Government as an item of elitist luxury. Therefore, air Conditioning equipment was subject to heavy taxes of upto 200% (import taxes, if imports were permitted at all, were even higher !!). Mercifully, the onset of liberation has brought about significant changes and today Air Conditioning is classified as less of a luxury. It may be some time before it is seen as a basic necessity, but we are bullish that this will happen pretty soon.

Now, here is a huge opportunity for Cogen : India is a country where 900 million people live for most part of the year under warm weather conditions. Even if we consider a small percentage of this population (basically urban population living in clustered apartments) as a target, the potential it offers for air conditioning is large. Given the problems of Power availability and cost, conventional Electrical cooling will be expensive and next to impractical. (Add to this the CFC and ozone layer depletion problem associated with conventional chillers). On the other hand, the idea of providing inexpensive cooling, using the tail-end waste heat of a cogen system through Absorption Chillers, offers a singularly large and untapped potential.

5. Next to Power, one of the major resource crunch looming large on India's infrastructure, is the availability of water : potable water, domestic water, industrial water - all are going to be in acute short supply by the turn of this century. Not just availability, but, even quality of water is going to be a bottle-neck. In many places, the summer water table goes down so substantially that what is available is highly brackish water. With growing industrialization, post liberalization, the availability of this precious resource is going to be even more critical.

Bad water in India is currently being treated by the conventional Demineralization (DM) process. The DM process has a limitation on how bad a water it can treat, largely determined by the Total Dissolved Solids (TDS) in the raw water. Beyond a certain TDS, the DM process is rendered ineffective. By way of a solution to the problem, industries in India adopt the Reverse Osmosis (RO) route which accepts high levels of TDS. But the RO process also has a problem - it is a Power guzzler. The solution - Thermal Desalination, which uses Thermal Energy instead of electrical Energy to treat water. What is fascinating is that Thermal Desalination can take in its stride almost any grade of heat energy from 70 ° C hot water to high pressure steam.

The opportunity : From a Cogen point of view, Thermal Desalination becomes a very natural adjunct as a heat host. More important, given the flexibility in the grade (temp.) of heat that can drive a thermal desalination process, it can boost the efficiency of the Cogen process through enhanced recovery of even low grade of heat.

6. Having looked at the application/system side of Cogen, let us take a look at the supply or fuel side options of a Cogen System. And this opens up a wide variety of options available right across the country.

   a) In the non-conventional area, we have a wide spectrum of agricultural residues including rice husk, soya husk, rice straw, wheat straw, bagasse and a host of other biomass.

   b) In the conventional area, we have coal, lignite as well as light and heavy oils. In the last budget, our Finance Minister has decanalised other light fuel oils like, Naphtha and Kerosene. What is of added significance is that Naphtha and Kerosene are now available with practically zero import duty.

   c) In the future (probably by the beginning of 2000), the availability of gas from the Oman-India Gas Pipeline is

expected to provide gas as an optional fuel for industry (existing Gas supply in India is fully tied up with current users).

Therefore, we now have a fuel availability position that offers immense flexibility for configuring high efficiency low cost Cogen plants to suit individual industry needs and locations.

7. Finally, a large portion of the equipment going into a Cogen plant (Boilers, Electricals, Instrumentation, water treatment, pollution control equipment, etc...) is inexpensively and easily available in India. And, unlike earlier times, the import of Cogen equipment like the prime movers (Gas Turbines, Steam Turbines, boilers, etc...) is now freely allowed. Additionally, import of used/reconditioned equipment (which is available in the developed world) has also been liberalized.

All this goes to provide a cogenerator enormous flexibility to configure the most optimal and cost effective system, keeping the Energy balance, fuel availability and equipment specs options in focus.

IV. WHAT NEEDS TO BE DONE

1. It may come as a pleasant surprise to many of us that even in countries like Europe, Japan and the United States, where the quality and availability of power is no problem at all, Cogeneration has been actively pursued and implemented by industry as viable mode of decentralized (inside the fence) power generation option. I am aware of industries who have adopted Cogen plants for as small a capacity as 500 KW with mouth watering operating benefits.
2. If this (the cogeneration option) is true of power surplus countries elsewhere in the world, it should also be true for a country like India where basic availbility of power is a night mare.
3. Thinking aloud, I would like to share some thoughts on the issues, hurdles and suggestions that we need to focus ourselves on to make Cogeneration take off in big way in India.
4. <u>IPP's versus CPP's (Cogen Power Plants)</u>

Earlier, I talked about the many MOU's that people have signed for supplying power to the State Electricity Boards and which have unfortunately not taken off the ground for a variety of reasons. If these MOU's can be looked at as inside the fence Cogeneration plants for industries as oposed to IPPs (which sell power to the grid), a win-win situation clearly emerges. :

- A private entreprenuer would be happy to pay a price which he would anyway have paid to the grid !
- Likewise steam would also be priced effectively so that he would pay what was otherwise an expense for his own steam generating plant.
- Since, it is a deal between two private enterprises which ensures effeciency of performance and effectiveness of payments a regular commercial deal can be easily configured (no soverien guarantees/ counter guarantees!).

What is required is a mind set change-. instead of making a bee-line for IPP MOU's with the State Electricity Boards, focus on

CPPs directly with industries. This is workable, achievable and realistic.

5. Liquid Fuel Policy:

   On the domestic liquid fuel policy, it is imperative that the government (Ministry of Power) comes out with a clear direction on sanctions and availability of a wide variety of liquid fuels from and with a single window clearence for all sanctions within the power ministry. Currently, the issue is being tossed between ministry of power and petroleum.

   This is notwithstanding the fact that import of some of the liquid fuels has been decanalised.

6. State Electricity Board Policies:

   There still exist some electricity boards who are reluctant to permit easy captive generation. If this can be reviewed and eased out, it would help the cause of cogeneration a great deal.

V. PROPAGATING THE CAUSE OF COGENERATION

At the outset I had complimented Dr. Pachauri and the TERI team for organising this workshop on cogeneration. I would like them to take this one step further and form **AN INDIAN**

COGENERATION ASSOCIATION something on the lines of COGEN EUROPE or ASEAN COGEN. This would act as a single point nodal agency for sharing, collating and desiminating the fund of global cogen knowledge and experience so that cogeneration, in the next few years, becomes the buzz word and in the process provide some real solution to the Indian POWER STUGGLE.

REGULATORY ISSUES REGARDING PRICING POLICY, WHEELING & BANKING CHARGES FOR COGEN POWER

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Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

REGULATORY ISSUES REGARDING PRICING POLICY, WHEELING & BANKING CHARGES FOR COGEN POWER

By
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1. INTRODUCTION

Presently contracts for sale of Electricity in India is governed by Clause 43 of I.E. Act (1948) together with the amendments issued by the Government from time to time. These amendments are mainly to facilitate entry of Private Power Producers in Power Generation.In the Act no special provision exists in regard to sale of surplus cogenerated power. Political and legal situation in regard to sale of cogen power is somewhat ambiguous both at the Central and State Level. Except for 2/3 SEBs, no other utility has so far made any provision for wheeling & banking of cogen power. Formulation of firm guidelines for the sale of cogenerated power is urgently needed in the interest of development of cogen power in India. Especially a suitable provision enabling cogenerators to sell at least a specified percentage of their generated power to third party consumers without obtaining SEBs permission will go a long way in attracting investments in the field of cogeneration.

Thus the main issues to be considered in this connection are :

(i) Pricing policies for sale of cogen power.

(ii) Wheeling of cogen power over existing networks of SEBs - formulation of guidelines for fixing wheeling charges.

(iii) Banking arrangements with utilities - guidelines for fixing banking charges.

2. PRICING POLICY OF COGEN POWER

2.1 BRIEF REVIEW OF US SCENARIO

In USA, under PURPA (Public Utilities Regulatory Policies Act) it is mandatory for public utilities to buy cogen energy on principle of Avoided Cost or Marginal Cost. Avoided cost is the incremental cost to the utility that it will either generate itself or purchase from outside

sources. FERC (Federal Energy Regulatory Commission) however has not laid down a consistent methodology for its application and the decision in this regard is left to individual states, resulting in a variety of practices being adopted. This has resulted in pricing cogen power at rates which bear little resemblance to 'avoided cost'. Another drawback of PURPA is that it forces the utilities to buy cogen power regardless of reliability and quality of power from this facility, or whether the utility needs the additional capacity. It is seen therefore that while PURPA has been instrumental in increasing the quantity of cogeneration (and independent power), in USA it did not help in development of efficient non-utility generation because of the element of compulsion imposed by the government on the utilities irrespective of their profitability consideration.

However, this distortion in PURPA has been rectified to some extent after the enactment of EPACT (Energy Policy Act of 1992). EPACT has broadened the scope of PURPA and removed many uneconomic guidelines and restrictions imposed by PURPA which provides for the framework for the ultimate transition to competitive generation. Thus EPACT is an improvement over PURPA, and has encouraged development of cost-efficient generation by introducing element of competition in building cogen capacity.

It may however be noted that in USA the PURPA is still in force and continues to protect and promote development of cogen facilities.

2.2 PRICING POLICY OF COGEN POWER IN INDIAN CONTEXT

For formulating a pricing policy for cogen power in India, it has to be ensured that the policy should not only be fair to cogenerator, but also to the buying utility keeping in view the poor financial health of most of the SEBs. Therefore the viewpoint of both the parties have to be kept in view.

Ideally from cogenerators viewpoint :

(i) Utility should pay the cogenerator on 'Avoided Cost' principle
(ii) Utility should consider power from cogen sources as firm power augmenting the utility capacity for meeting their base load demands.
(iii) Therefore utility should be ready to pay the cogenerator towards both capacity and variable costs.

SEB's perception

(i) Since utilities do not have any experience regarding reliability of power supply from cogen plants, they would hesitate to recognize this as source of firm power.

(ii) Cogen power may not be available during off-season for the relevant industry.

(iii) Technical difficulties in running of small sized cogen generating units in synchronism with SEB grid.

(iv) SEBs are normally surplus in off-peak-hours, and require assistance particularly during peak hours.

Taking into consideration the view points of both the concerned parties, following pricing structure is suggested for buying utilities.

(i) Upto 68% PLF, the price of cogen power should be such as to ensure 16% return on equity or the cost/unit generated at the SEB's costliest thermal station- whichever is lower.

(ii) Beyond 68% PLF: During off-peak hours when SEBs system is surplus in power, the cogen power would have to be sold at competitive rates (which should be lower than SEBs rate).

For direct sale of power by Cogenerator to a Bulk consumer, the sale price would have to be at mutually acceptable rates. Some of the factors that would determine pricing would be : reliability and quality of existing supply from SEB's grid vis-a-vis the cogenerators power supply, degree of reliability of power supply desired by the consumer, importance of continuity and quality of power supply in the manufacturing process of the consumer etc. Thus the pricing for third party sales would have to be on case to case basis taking into consideration the guidelines laid down by the concerned regulatory body in this regard.

2.3 BANKING OF COGEN POWER

In an energy banking transaction between two parties the surplus energy available in power system 'A' is made available to an adjoining system 'B' for their use on the understanding that the same would be returned to them (A) whenever needed. For this service, system 'A' has to pay a banking fee to the system. Such transactions normally cover situations where one of the utilities has spare storage capacity in its hydro reservoirs to absorb spilt hydro/surplus thermal energy available in a neighboring utility. For example, In the Northern Regional Power System of India, Himachal Pradesh Electricity Board System has surplus power in summer but is deficit in winter. HPSEB banks its surplus power with neighboring Punjab State Electricity Board (PSEB) system and draws equivalent energy during winter. This is actually done by mutual adjustment of the allocated shares of Punjab & Himachal Pradesh in the Bhakra Hydro-Electric Project.

Concept of Banking is useful in the context of cogen power also. Surplus power with the Cogenerator (i.e. the generation available with cogenerator in excess of the loads of its consumers at a particular point of time) could be supplied to the SEB with the understanding that equivalent energy would be returned when required. For this service the utility would naturally have to be paid a nominal fee. However under the power availability shortage conditions in India (which is likely to continue for quite a few years to come) the feasibility of successful implementation of banking transaction between Cogenerator and SEB is rather doubtful. Almost all SEBs are facing power shortage except during night hours. Thus SEBs would normally be in a position to return the banked energy to the Cogenerator only during off-peak periods when the Cogenerator would not need energy assistance. Therefore in case the SEB is unable to honour its commitment to return the banked energy to the Cogenerator during the specified hours of the day, the SEB must treat the banked power as power sold to it at contracted rate and pay the cogenerator accordingly.Duration of agreement for banking transaction should be limited to one year only which could be renewed on annual basis.

As regards banking charges, one could consider that cogen energy banked with the utility goes to meet the load demand of the utility. In other words, cogenerator 'deposits' energy with the utility on 'credit' basis which is utilized by the SEB for supplying its consumers. For this the utility is not required to pay any 'interest' charges. Therefore one view could be that cogenerator should not be asked to pay any banking charges. At the most, a nominal banking charge of 0.5 to 1% of energy banked (not energy generated) could be levied. Banking period/charges applicable to Cogen as per existing guidelines/policies are :

Tamil Nadu..	2% of Energy generated for 3rd party &2% for sister concern within 25 km radius.
Karnataka...	6% of energy generated for 3rd party.
U.P....	One year/Banking charge not specified.
M.P...	Not specified
Punjab...	Not specified
MNES.... (Guidelines)	One year/No charges

RECOMMENDED

(12) Recommended Banking Period/Charges :

Period : One year
Charges : 0.5 to 1% of energy banked (not of energy generated)

2.4 WHEELING OF COGEN POWER

Wheeling means transfer by direct transmission or displacement of electricity from the Cogen plant to a consumer over the facilities of the host SEB. For this the cogenerator is required to pay the SEB "Wheeling Charges" for making use of the transmission and distribution facilities of the host utility. Wheeling charges payable to host SEB are expected to cover following two factors :

- Rental charges for the T&D facilities made available by the SEB.
- Charges to cover the cost of incremental losses due to superimposition of cogenerator's power over the SEB's power on the T&D system.

Rental Charges

Annual rental charges payable by cogenerator to SEB should be based on the "Annual Costs" of the T&D system of the SEB. "Annual Costs" comprise :

(a) Interest & Depreciation charges

(b) O&M and Establishment costs

Representative "Annual cost" of T&D of a typical SEB is about Rs 587/kW or say Rs 600/kW i.e. Rs 6 lakhs/MW. Considering a 25 MWcogen plant, the corresponding annual cost for T&D would work out to Rs.150 lakhs. As against this, the annual revenue earned by the Cogen plant from sale to SEB say @ Rs 1.50/unit (operating at 70% PLF) would be Rs 2300 lakhs/year. Therefore "Annual T&D Charges" as a percentage of "Annual Revenue" earned, works out to Rs 150 lakhs x 100 = 6.5%. Annual Rental charges for T&D facilities used by cogenerator could be in the range of 6-6.5%. It may be noted this figure is indicative, the actually charges may vary from SEB to SEB depending on the individual cost and other technical parameters.

Incremental losses

For appreciating the magnitude of superimposed load of the cogenerator on the SEB system as compared to the size of an SEB system let us take some concrete figures.

Sizes of some of the SEB systems are :

MSEB	: 7000 MW
GEB	: 5500 MW
UP	: 5200 MW
WBSEB	: 2000 MW

It may be appreciated that injection of mere 10-20 MW from cogen plant to an SEB system 150 to 700 times its size would hardly have any effect on the T&D losses (incremental) on the SEB.

As a matter of fact, it is quite possible that the cogen power injected into the grid may actually help in reducing the SEBs T&D loss. This is because, the injected cogen power would flow to the intended consumer by displacement of power flows in the transmission

network and not by physical flow of the cogen power to the intended consumer. It is felt therefore that no charges need to be levied by SEB towards compensating the SEBs incremental losses. Thus, wheeling charges @ about 6-6.5% of the energy wheeled through the SEB system could be considered to be fairly reasonable.

Wheeling charges applicable to cogen as per existing guidelines/practices are as follows:

Tamil Nadu...	2% of Energy generated for 3rd party and 2% for sister concern within 25 km radius.
Karnataka...	6% of energy generated.
U.P....	12.5% of energy generated
M.P....	2% of energy generated
Punjab....	2% of energy generated
MNES (Guidelines)..	2% of energy fed into the grid irrespective of distance from generating station.

3. CONCLUSION

It is true that all possible encouragement should be given to the cogenerating industry for utilizing the huge untapped cogeneration potential estimated to be of the order of 15000 MW in the Indian industrial sector. This option offers a commercially attractive alternative to augment the power availability of the SEBs which are plagued by massive power shortages as well as financial crunch. The guidelines to be formulated for the pricing policy including banking and wheeling charges applicable to cogen sector should therefore to take into consideration the interests of both the seller and buyer of the power and should be fair to both the parties. It has to be ensured that the investor in cogeneration sector earns a fair return on his investments. At the same time, although initially the cogenerating sector would need some amount of 'hand holding' by its big brother, the utilities, it is to be remembered that the most of the SEBs are on the verge of bankruptcy and therefore their capability of giving support in commercial terms is severely restricted. These factors have been kept in view while suggesting the following guidelines relating to pricing, banking and wheeling of cogen power:

Pricing of Cogen power

(1) Upto 68% PLF :

Pricing should be such as to ensure 16% Return on equity OR the cost/kWh generated at the SEB's costliest Thermal Power Station - whichever is lower.

(2) Beyond 68% PLF (i.e. during off-peak periods) :

Cogen power to be sold at competitive rates i.e. at rates below SEB's rate.

Banking Charges

Banking Period : One year
Charges : 0.5 to 1% of energy banked

Wheeling Charges

6-6.5% of the energy wheeled.

CO-GENERATION IN SUGAR INDUSTRIES : POTENTIAL & PROSPECTS IN INDIA

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Co-Generation in Sugar Industries : Potential & Prospects in India

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Introduction

India's involvement in Renewable Energy movement is being reported to be the second most extensive in the developing countries next only to China. The growth in this sector can be attributed mainly to the favourable policy and financing environment existing in the country and concern for environment conservation and sustainable development. Several international development financial institutions like the World Bank (WB), Asian Development Bank (ADB) and the United States Agency for International Development (USAID) have shown interest and are involved in the financing of renewable energy projects.

In order to meet the growing demand for power supply, the Government of India is likely to add some 20,000 MW generating capacity through conventional sources besides 2000 MW through renewables including co-generation mostly through private sector initiative, during the VIII five-year plan (1992-97).

India is currently the largest producer of cane sugar in the world, accounting for 10 % of the world production. Sugar is a growing industry with the cane area, yield and recovery of sugar increasing over the decades, though there are cyclical variations from year to year. Though the concept of bagasse based co-generation has always been practiced by sugar mills, there has of late been growing awareness in the sugar industry of the advantages of installing 'high efficiency' bagasse based co-generation systems. The sugar mills have been further encouraged by favorable policies announced by the Government of India, the State Governments and various State Electricity Boards.

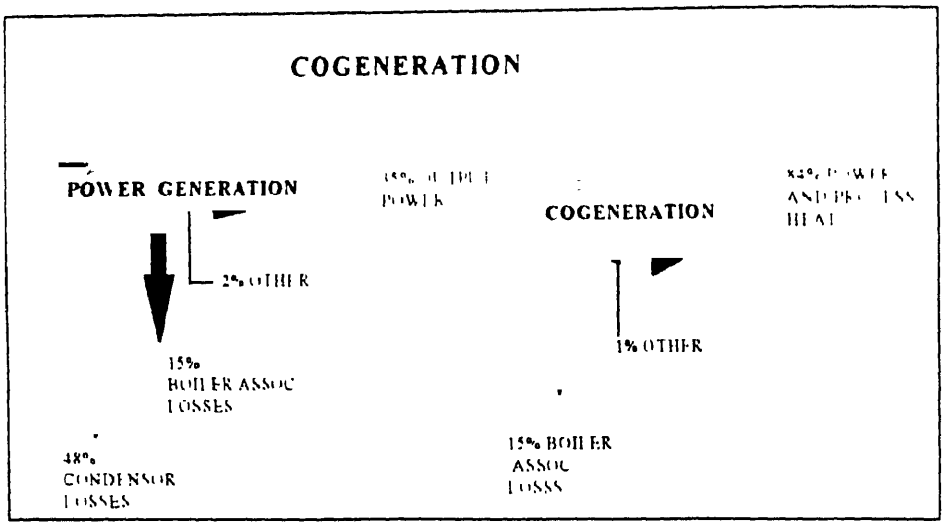
Co-Generation - The Concept

* Cogeneration is defined as the concurrent generation of process heat and motive power in an industry by the sequential use of energy from a common fuel source.

* Depending on the quality of process heat required, co-generation may be based on topping cycle or on bottoming cycle.

* In bottoming cycle systems, heat is required for the process at high temperature and hence power is generated through a suitable Waste Heat Recovery System.

* On the other hand, in the topping cycle system, heat is required for the process at low temperatures and therefore power generation is taken up first. All sugar mills employ this cycle for co-generating power and heat.



The process of manufacturing crystal sugar requires steam. In existing co-generation systems steam is generated in low pressure boilers by using bagasse-the woody fibrous residue of crushed cane, as fuel. This system was developed when possibility of exporting power to the grid was not envisaged. Further, since the storage of large quantities of combustible bagasse in the premises of the sugar mill was not an advisable option, most of the boilers were designed so as to use almost the entire quantity of bagasse produced. There is thus a `built-in energy inefficiency' in the sugar factories using all the bagasse as fuel for their low pressure boilers. By upgrading the steam parameters, the sugar industry can produce electricity far in excess of their own requirement and sell the surplus power to the grid.

Benefits Of Adopting High-Efficiency Co-Generation Systems In Sugar Mills

1. Not depending on external power at all, sugar plants can be located nearer the sugar growing areas, thereby saving on transportation cost of sugar cane.

2. An efficient and sustained co-generation enables the plant to isolate itself from the vagaries of power.

3. Power generation using bagasse is environmentally cleaner as bagasse produces very little fly ash, and no sulphur.

4. Net contribution to greenhouse effect from the bagasse based co-generating plant is zero, since the carbon-di-oxide absorbed by the sugar cane grown is more than the one emitted by the co-generating plant.

5. Low gestation (18-24 months) as compared to 96-120 months for a coal based power plant.

6 Low capital investment. Recurring costs are also lesser compared to fossil fuel based power plants.

7. Use of a totally renewable source of energy. Total saving in the mining, extraction and long distance transportation expenses of fossil fuels.

8. Rural location of sugar mills enables co-generated power to be directly fed to the local sub station, consequently minimizing T & D losses and the requirement of long feeder lines.

9. Benefits of quick return on cogeneration capital investment.

10. Saves the expenditure on safe storage and disposal of bagasse.

11. A cogeneration plant places no financial or administrative burden on the utility as it is executed and managed by the sugar factory.

12. Power is generated at a lower cost in cogenerating systems and pay back periods are shorter.

13 Provides an initiative to sugar mills to concentrate more on conservation of energy and reduction of steam consumption thereby improving their profitability of operation.

14. Surplus power generation in sugar factory is ideally suited for rural electrification and for energising irrigation pumps and industrial and agro-based units in the villages.

15. Even among the renewable energy projects, this perhaps is the only sector which has readily available infrastructure.

Potential For Bagasse Based Co-Generation : The Indian Sugar Industry

Sugar production in India takes place in 18 States. The following table gives the statewise break-up of the 427 Indian sugar mills in different states.

Statewise Sectoral Break-up of Sugar Mills in India

Sl. No.	State	Joint Sector	Public Sector	Co-op. Sector	Total
01.	Uttar Pradesh	44	35	31	110
02.	Maharashtra	5	-	104	109
03.	Andhra Pradesh	10	8	18	36
04.	Tamil Nadu	14	3	15	32
05.	Karnataka	11	3	17	31
06.	Bihar	14	15	-	29
07.	Gujarat	-	-	19	19
08	Punjab	4	-	15	19
09.	Haryana	1	-	10	11
10.	Orissa	7	-	1	8
11.	Madhya Pradesh	2	3	3	8
12.	Kerala	1	-	2	3
13.	Rajasthan	1	1	1	3
14.	Assam	1	1	1	3
15.	West Bengal	1	1	-	2
16	Pondicherry	1	-	1	2
17	Nagaland	-	1	-	1
18.	Goa	-	-	1	1
	TOTAL	117	71	239	427

The cane crushing season in India is during the period of `November to May' and lasts on an average for 200 days.

The size of sugar plants in India, in terms of daily cane crushing capacity, varies from 1250 TCD to 5000 TCD and above. The minimum size of a sugar mill has now been stipulated at 2500 TCD.

The following table gives the state wise break-up of sugar mills in India based on their licensed cane crushing capacity.

Capacity Wise Break-Up of Sugar Mills in India

Sl. No	State	≤ 1250 TCD	< 2500 TCD	2500 TCD	< 5000 TCD	> 5000 TCD	Total
01.	Uttar Pradesh	44	18	29	12	7	110
02.	Maharashtra	44	18	26	15	6	109
03.	Andhra Pradesh	22	4	6	1	3	36
04.	Tamil Nadu	6	7	13	4	2	32
05.	Karnataka	15	5	6	1	4	31
06.	Bihar	15	10	3	0	1	29
07.	Gujarat	7	1	4	3	4	19
08.	Punjab	6	2	9	1	1	19
09.	Haryana	5	2	3	0	1	11
10.	Orissa	5	0	3	0	0	8
11.	Madhya Pradesh	7	1	0	0	0	8
12.	Kerala	3	0	0	0	0	3
13.	Rajasthan	2	1	0	0	0	3
14.	Assam	3	0	0	0	0	3
15.	West Bengal	2	0	0	0	0	2
16.	Pondicherry	1	1	0	0	0	2
17.	Nagaland	1	0	0	0	0	1
18.	Goa	1	0	0	0	0	1
	Total	**189**	**70**	**102**	**37**	**29**	**427**

TCD: Tonnes of cane crushed per day

A typical sugar mill has the following features :-

1. Bagasse produced by crushing cane is 30-35 % of the cane crushed.

2. Bagasse is burnt to generate steam in boilers. The steam pressures encountered range from 15 in old plants, 21 in plants installed in the seventies and 32 to 43 kg/cm^2 in mills installed since the mid - eighties.

3. Operating at low pressures, the mill can use almost the entire bagasse for process steam generation thereby avoiding accumulation of bagasse and eliminating the need to make provisions to store bagasse.

4. Process steam consumption is 50-55% of the cane crushed.

5. Mill wet bagasse produced contains about 50% moisture - (48-52%). The gross calorific value of mill wet bagasse (50% moisture) is 2280 kCal/kg. The proximate and ultimate analysis of mill wet bagasse is as under :

Proximate Analysis	Ultimate Analysis
Fixed Carbon - 11.5 %	Carbon - 22.5 %
Volatiles - 37 %	Hydrogen - 3.0%
Moisture - 50 %	Oxygen - 23.0 %
Ash - 1.5 %	Ash - 1.5 %
	Sulphur - traces

Co-Generation Potential in India

A number of studies have been conducted to estimate the potential for bagasse based co-generation. The results of some of the more recent studies are as under:

1. In 1993, an MNES task force formed to study the potential of bagasse based co-generation, have estimated the potential at 3500 MW.

2. On the other hand, the Tata Energy Research Institute have estimated India's potential for co-generation in sugar mills as 5100 MW.

3. A third study conducted by USAID/Winrock International/IDEA Inc., in May, 1993 have reported that efficient co-generation could yield an additional 3800 MW of electric power.

4. The most recent estimation was made by an IFREE/dLA/IDS team, who have estimated the potential as 2800 MW with highly efficient mill operations and high pressure conditions.

However, bagasse based co-generation has a major drawback that the annual production period is usually limited to six to seven months. This period does not normally match with the seasonal variation in electric load demand. Bagasse availability period coincides with the surplus hydel peaks in some states, while in the peak summer months, sugar factories are shut down due to non-availability of cane. This constraint may be circumvented by spreading electric generation throughout the year, using available bagasse or by resorting to other fuels in the off-season.

Possible Models Of Co-Generation

The following are a few possible configurations recommended for designing a co-generation system in new plants by the MNES task force. For existing plants, there are number of options which are to be worked out on case-to-case basis incorporating energy conservation measures.

A. Extraction cum Back pressure Route

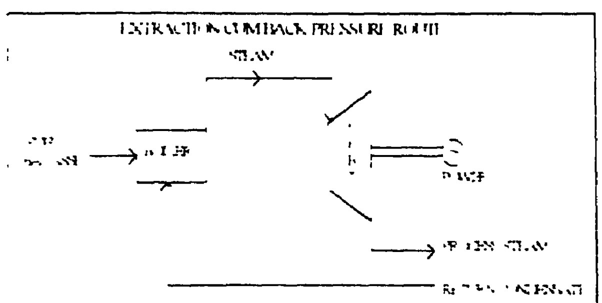
The main features of this configuration are as under :

* Sugar Factory produces steam only to the extent of process steam requirement

* By upgrading the steam parameters, surplus power is produced after meeting captive requirement.

* Surplus power production is envisaged only during crushing season.

* Cheapest option from the point of view of initial cost and efficiency of the system.



EPBT Extraction cum Back Pressure Turbine

* Has the disadvantage that fluctuation in surplus power supply is related to fluctuation in cane supply and fluctuation in process steam demand etc.

B. Extraction & Condensing Route through Bagasse Fuel System

* The sugar factory produces steam by using the entire bagasse produced, during the crushing season.

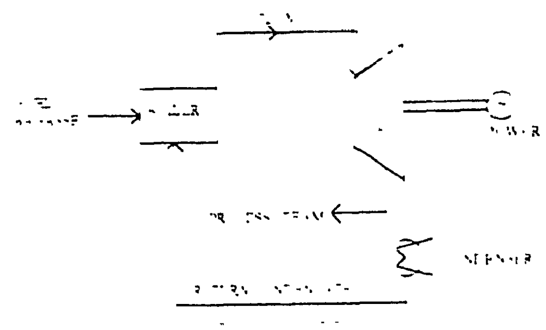
* By using an extraction and condensing turbine, surplus power production can be extended during off season by operating the turbine in the condensing mode.

* Power can be generated by using bagasse bought out from nearby sugar mills or by using bagasse saved during the latter part of the crushing season.

- Capital cost is higher for this option.

- Ensures supply of stable surplus power during crushing season thereby reducing fluctuations in sugar plant operation.

EXTRACTION AND CONDENSING ROUTE THROUGH BAGASSE FUEL SYSTEM



ECT Extraction and Condensing Turbine

C. Condensing Route Based on Dual Fuel System.

This option has the facility of year round stable surplus power supply using a support fuel.

- This is viable for sugar mills located near the source of a secondary fuel.

- In such an option the reliability of alternate fuel supply has to be ascertained. Design aspects of the boiler also need to be examined to ensure availability of proper furnace capable of multi fuel combustion particularly the combination of bagasse with coal/lignite.

- Besides, the capital cost of the multi fuel systems, particularly while using coal as support fuel will be high along with connected problems of pollution control and ash disposal.

- Highly skilled manpower is required for operation and maintenance of such an advanced technology

CONDENSING ROUTE BASED ON DUAL FUEL SYSTEM



EPBT Extraction cum Back Pressure Turbine

In addition to the above options, the following simple energy conservation measures, if adopted, can contribute to the surplus power generation:

* Replacement of turbo drives used for cane preparation and milling by hydraulic or electric drives.

* Reduction of process steam consumption from the existing level (50-55 % on cane) to 42-45% by incorporation of modifications in juice heating and evaporation system.

* Increasing efficiency of boiler operation from the existing average of 60% to at least the minimum stipulated value of 70%.

* Introduction of more controls and instrumentation in power plant operation.

* Use of bagasse driers to reduce the moisture content in bagasse before it is fired in the boiler.

In order to derive maximum power availability from a co-generation system, it would be necessary to ensure maximum energy economy and optimum system configuration. This would also ensure high efficiency at minimum cost and adequate safety. Modular standardization of capital equipment and reuse of displaced capital plant elsewhere can substantially reduce the cost of upgrading co-generation in the existing plant.

MNES Task Force for Biomass Based Co-Generation

The MNES had constituted a task force of experts in August, 1993 to formulate a policy for the Government of India for a National programme on Biomass Based Co-Generation.

The task force which had deliberated on issues of potential, technologies and constraints, identified a potential of 3500 MW of surplus power which could be generated from the sugar mills .

The task force recommended the following steps to be taken by the Government to propagate co-generation in the Indian sugar industry.

* Announce a policy on
    1. fiscal/financial incentives for cogeneration systems
    2. subsidies/ grants for demonstration projects.

* Formulate norms for co-generation schemes which would be eligible for incentives.

* Formulate standard procedures for calculation of rate of return and selling price of power from co-generation plants, keeping in view opportunity cost of bagasse cost of supplementary fuels, if any, and minimum capacity utilization.

- Formulate model agreement with state utilities to receive power from the sugar industry co-generation.

- Evolve means of compensating co-generation schemes where the price of power offered by the state utilities does not give minimum 16 % post tax return on equity.

- Appoint suitable agencies to do detailed survey statewise to assess co-generation potential and shortlist prospective mills for demonstration projects.

National Programme on Bagasse Based Co-Generation

Based on the recommendations of the task force, the MNES had launched a National Programme on Bagasse Based Co-Generation in January, 1994

The main objectives of the programme are :

I. Creation of conducive conditions for adoption of high efficiency co-generation schemes in Indian sugar industry leading to early exploitation of the estimated potential of around 3500 MW for surplus power generation.

II. Development of indigenous capability and capacity of design, manufacture and operation of modern high efficiency co-generation plants.

III. Generation and supply of 300 MW of power through bagasse based co-generation in Indian sugar industry during the VIII Plan Period.

The components of the programme include :

I. Non-recurring capital subsidy (upto 30% of the equipment cost or upto Rs. 70 lakhs/MW of net surplus power, whichever is lower) for projects that envisage the generation of at least 5 MW of surplus power using boilers which generate steam at a pressure of 60 bar or higher. However, the maximum amount of subsidy to any cogeneration project will be limited to Rs. 60 million in case of existing sugar mills. In case of new sugar mills the Subsidy will be at half of the above mentioned levels. A maximum of 12 demonstration projects are proposed to be taken up in sugar mills in major sugar producing states in the country. Out of the 12 projects planned to be supported under the programme, 9 will be in the co-operative/public sector The projects will be taken up in those states which have announced a general policy for purchase of surplus power generated.

II. Soft - semi commercial loans for projects which envisage production of at least 4 MW of surplus power. Under this activity MNES will provide grants (upto max. of 20 lakhs/MW of surplus power) to FIs like IDBI,IFCI,ICICI,NCDC,IREDA, etc to enable them to reduce interest rates by 2% on their lending (upto 60% of the project cost) to eligible sugar mills.

III. Assistance in the form of grant to the extent of upto 50 % of the cost of preparation of Detailed Project Reports, subject to a maximum of Rs. 4.0 lakhs.

IV. Support to Research & Development projects in the areas of bagasse drying, bagasse storage and baling, fluidized bed combustion and gasification of bagasse.

V. Support to information dissemination, training and assessment studies.

Under the National Programme, the following sugar mills have been sanctioned in-principle a subsidy for surplus power co-generation

Projects Sanctioned under the National Demonstration Programme

Sl. No.	Name of the Sugar mill	Mill Capacity	Net Exportable Power	Subsidy Amount (Rs. in Lakhs)
1.	EID Parry (I) Limited, Tamil Nadu	5000 TCD	10.76 MW	450.25
2.	Kothari Sugars & Chemicals Ltd, Tamil Nadu	3500 TCD	9.90 MW	268.35
3.	Malaprabha Coop. Sugar Mill, Karnataka	3500 TCD	18.10 MW	600.00
4.	Thiru Arooran Sugars Limited, Tamil Nadu (Unit # 2)	2500TCD	9.20 MW	343.00

IREDA's Role In Promoting Bagasse Based Co-Generation

The Indian Renewable Energy Development Agency has been entrusted with the responsibility to promote bagasse based cogeneration as a part of renewable energy development programme. In addition to this, IREDA also finances cogeneration projects based on other biomass fuels The norms of financing under this programme are as follows:

IREDA's Norms of Financing

Minimum Promoters contribution	25 %
Term Loan	Upto 75 % of project cost
Interest rate (inclusive of interest tax)	16.5 %
Total repayment period (inclusive of moratorium)	10 years
Moratorium (Maximum)	3 years

IREDA has so far financed the following bagasse based co-generation projects :

IREDA Financed Co-Generation Projects

YEAR	Promoter	Project Cost	Total Loan	IREDA Loan	Remarks
1993-94	Narmada Sugars Limited, Khargone, M.P	505.00	378.75	200 00	3 MW captive co-generation plant Fully disbursed. Project has been commissioned in February' 95.
1994-95	Rajshree Sugars & Chemicals Ltd. Madurai, Tamil Nadu	1300.00	850.00	850.00	12 MW co-generation plant. Operation only during crushing season. Export of 7 5 MW envisaged.
1995-96	Dharani Sugars & chemicals Ltd.	3815.00	2861.00	500.00	15 MW Cogeneration plant Operational round the year with lignite as fuel during off-season Export power during season 8 27 MW & in off-season 13 47 MW
1995-96	Thiru Arooran Sugars Ltd. (Unit # 1)	4590.00	3440.00	2000.00	19 MW Cogeneration plant. Operational round the year with lignite as fuel during off-season Export power during season 9 2 MW & in off-season 16 7 MW

Technical parameters of the above projects are given in the following table :

Bagasse Based Co-Generation Projects Financed by IREDA

Name	NSL	RSCL	DSCL	TASL
State	MP	TN	TN	TN
Year of Sanction	1993	1995	1995	1995
Installed Capacity				
- Sugar Mill (TCD)	2500	2500	2500	2500
- Co-Generation Plant (MW)	3	12	15	19
Surplus Power (MW)	Nil	4	8.3/13 5	9.2/16 7
Fuel	Bagasse	Bagasse	Bagasse/Lignite	Bagasse/Lignite
Boiler Details				
Make	WIL	KCP	WIL	BHEL
Pressure (kg/sq cm)	32	43	64	67
Temperature (Deg C)	380	430	485	485
Capacity (t/h)	(2 x 35 t/h)	(2 x 35 t/h)	(1 x 80 t/h)	(1 x 70 t/h)
Turbine Details				
Turbo/Alternator Make	Triveni/BHEL	Triveni/BHEL	DLF	GAT
Turbine Type	BPT	UEBPT/CECT	SBSECT	SBSECT
Turbine Rating	(1 x 3 MW)	(1 x 6 MW)/ (1 x 6 MW)	(1 x 15 MW)	(1 x 18.68 MW)
Means of Financing				
Project Cost (Rs in Cr.)	5.05	13.00	38 15	45 90
IREDA Loan (Rs. in Cr)	2 00	8 50	5.00	20 00
(% of project cost)	39 60%	65.38%	13 11%	43 57%
Date of Commissioning	January, 1995	March, 1996	March, 1996	October, 1996

Legend

NSL : Narmada Sugars Ltd.
RSCL : Rajshree Sugars & Chemicals Ltd.
DSCL : Dharani Sugars & Chemicals Ltd.
TASL : Thiru Arooran Sugars Ltd.

WIL : Walchandnagar industries Ltd.
GAT : GEC Alsthom Triveni Ltd.

BPT : Back Pressure turbine
UEBPT : Uncontrolled Extraction, Back Pressure Turbine
CECT : Controlled Extraction, Condensing Turbine
SBSECT Single Bleed Single Extraction, Condensing Turbine

IREDA is presently being appraised by the Asian Development Bank for a US$ 150 million line of credit for various renewable energy technologies including bagasse based co-generation.

IREDA has also commissioned an All India Study on Bagasse Based Co-generation through the Maharashtra Industrial & Technical Consultancy Organization (MITCON), Pune. The key issues that will be dealt with in the study include generation of project pipeline for IREDA by identification of sugar mills with potential for surplus power generation using bagasse and to identify and evaluate key issues of bagasse based co-generation projects for quick and successful implementation of such projects.

Private Power Environment In India

The Government of India has targeted a capacity addition to the extent of 2000 MW through renewable energy including 300 MW through bagasse based co-generation. In order to achieve this target of power generation, the Government of India has announced several measures to promote independent power production. These measures include :

* Upto 100 % foreign equity participation
* Flexible power sales arrangements in which private power companies can act as licensees, supplying and distributing power to a given region or as generating agencies supplying power to the grid at large.
* 4:1 Debt -Equity ratio on investments.
* Single window clearance through a new investment promotion cell.
* ROI of 16 % based on 68.5 % PLF
* 30 year initial investment period, with subsequent 20 year extensions.
* 5 year tax holiday, with partial holiday through tenth year of project.

Fiscal Incentives By Govt. Of India

The other incentives offered for this sector are as under :

ITEM	DESCRIPTION
Income Tax	
01. *Depreciation*	100 % depreciation in the first year can be claimed for the following co-generation equipment : 1. Fluidized Bed Boilers 2. Back pressure, pass-out, controlled extraction, extraction and condensing turbine for co-generation along with boilers 3. High efficiency boilers 4. Waste heat recovery equipment
02. *Tax Holiday*	First 5 years - Nil, Next five years - 70 %.
Customs Duty	Duty leviable for NRSE power projects of less than 50 MW capacity (under Project Import Category) is 20 % ad valorum. this covers machinery and equipment component parts required for generation of electric power.
Central Excise Duty	Exempted for renewable energy devices, including raw materials, components and assemblies
Central Sales Tax	-do-
General Sales Tax	Exemption is available in certain States

State Govt. Policies For Co-Generation

The following table gives a summary of the incentives offered by various state governments in India :

State Government Policies and Incentives for Bagasse Based Co-Generation

Description	MNES Guideline	Tamil Nadu	Karnataka	Maharashtra	Uttar Pradesh	Madhya Pradesh	Punjab
Power Wheeling Charges	2 % of energy fed to the grid, irrespective of the distance from the generating station	2% of energy generated for 3rd party & 2% for sister concerns within 25 km radius	6 % of the energy generated for 3rd party. (Likely 5%)	Nil	12.5 % of the energy generated.	2% of the energy generated.	2% of the energy generated.
Power Banking Period/Charges	One year/Nil	2 % of energy generated.	6 % of the energy generated.	-	One year	Not Specified	Not specified.
Buyback rate by SEB	Rs. 2.25/kWh (min.) with 5% escalation without any restriction on time or quantum of electricity supplied.	Rs.2.25 /kWh, with 5% escalation every year for 5 years.	Rs.2.25/kWh	Rs.2.00/kWh for export upto 4 MW. Rs.2.25/ kWh for export above 4 MW. (Above rates for 6 years.)	Rs.2.25/kWh or at a rate which ensures a RoE of 16% and 68.5% PLF, whichever is lower.	Rs.2.25/kWh	Rs.1.50/kWh
3 rd Party Sale	Allow to HT consumers within the state at mutually agreed rate.	Allowed to HT consumers at mutually agreed rate.	Allowed.	Not Allowed.	Allowed to HT consumers at mutually agreed rate within a radius of 5 km.	Allowed to HT consumers at mutually agreed rate.	Allowed at mutually agreed rates.
Capital Subsidy	Subsidy given to industrial units in backward areas.	Nil.	Rs.25 lacs/MW (export)	For export > 4 MW, participation in cooperative mills by MSEB - upto 60 % of equity.	Nil	Not specified	As extended to other industries
Other Concessions	• Exemption from electricity duty. • Exemption from demand cut upto 30% of the installed capacity. • Sales tax benefits applicable to new industrial units • Infrastructural facilities similar to industrial estates.	1) Exemption from electricity generation tax	1) Exemption from electricity tax for 5 years for captive use. (Other modes - 4p per unit)	-	Nil	1) Exemption from electricity duty for 5 yrs. 2) Demand cut upto 30% of installed capacity. 3) Exemptions from sales tax and other concessions applicable to new industry.	1) Exemption from electricity duty 2) Demand cut upto 30% of installed capacity. 3) Exemptions from sales tax and other concessions applicable to new industry
Promotional Agency		TNEB	KSEB	MSEB	NEDA	MPUVN	PSEB

Current Co-Generation Activities In India

Co-generation activities in Indian sugar mills were restricted to the production of power required for captive use in the sugar mill and steam for sugar production process. Since the late eighties, there has been an increasing awareness of the advantages of surplus power generation from sugar factories, and some of them have taken steps to install medium pressure boilers (42 kg/cm^2) to generate surplus power for feeding to their ancillary units or to the state grid.

Two such sugar mills are the Daurala Sugar Works, Uttar Pradesh and Shree Datta Sehkari Shakkar Kharkhana, Maharashtra have been exporting nearly 1.5 MW of surplus power to nearby industrial units. Two other sugar mills in the co-operative sector in Tamil Nadu (the M.R.K.Cooperative Sugar Mills, Sethiathope and Cheyyar Cooperative Sugar Mills, both of 2500 TCD capacity) have installed co-generation plants having a power generating capacity of 7.5 MW in their premises. These sugar mills have been designed to export nearly 4 MW of power to the SEB grid.

The following sugar mills have commissioned bagasse based co-generation plants with surplus power export.

Bagasse Based Cogeneration Projects Exporting Surplus Power

(As on Dec '95)

Sl. No.	Name of the Sugar mill	Year of Commissioning	Exportable Power
1.	M.R.K.Co-Operative Sugar Mill Ltd., Tamil Nadu	1992-93	3.00 MW
2.	Cheyyar Co-Operative Sugar Mill Ltd., Tamil Nadu	1992-93	3.00 MW
3.	Shri Datta SSK Ltd, Maharashtra	1992-93	1.50 MW
4.	Shri Jawahar SSK Ltd, Maharashtra	1994-95	1.50 MW
5.	Deogiri SSK Ltd, Maharashtra	1994-95	1.50 MW
6.	Dhampur Sugar Mills Ltd, Uttar Pradesh, (Unit #1)	1994-95	1.50 MW
7.	Thiru Arooran Sugars Ltd, Tamil Nadu (Unit # 2)	1995-96	8.00 MW
Total Capacity Acheived			20.00 MW

Multi-Lateral Investment Programmes

The United States Agency for International Development, (USAID) is presently operating a 19 million US $, five year Greenhouse Gas Pollution Prevention Project which is considered a part of U.S contribution to the Global Environment Facility. The project aims at reducing greenhouse gas emissions by catalyzing Indian development of efficient coal and alternative bagasse/biomass energy approaches for power sector expansion within India's economic development programme. The project is meant to promote efficient power technologies that have not been demonstrated in India. The project has two major parallel components, namely,

- Efficient Coal Conversion (ECC)
- Alternative Bagasse Co-Generation (ABC)

This programme has a project investment component of US$ 12 Million and a technical assistance component of US$ 7 Million.

The ABC programme focuses on options for off-season power generation in sugar mills, so that sugar mills can supply firm power year round.

The highlights of the ABC Investment Component (US $ 9 Million), meant to buy down the cost of the commercial line to be established by the IDBI are as under :

- Aims at demonstration and commercialization of bagasse based co-generation plants that rely on supplemental biomass fuels rather than fossil fuels. The biomass fuels recommended are cane field residues, stored bagasse which has been saved by the adoption of energy conservation measures, biomass such as rice husk, rice straw, ground nut shells etc. and wood from energy plantations.

- This component will work closely with the sugar industry to provide the industry with information, technical assistance and training on all feasible options.

- The component will also cover the incremental costs and risks associated with the initial adoption of technologies and development of skills and knowledge needed for the introduction and use of supplemental biomass fuels by bagasse co-generation systems.

- The ABC projects will have a debt-equity ratio of 3:2.

The objective of the ABC TA Component (US $ 3 Million), is to provide the pre-investment support needed to help stimulate private sector investment in biomass/bagasse based co-generation projects.

In addition to the above project the Asian Development Bank is also in the final stages of firming up a US $ 150 Million aid for financing renewable energy projects including US $ 65 million for co-generation in India for on-lending through IREDA. The loan programme is expected to commence in April, 1996. As a part of developing a financing programme, IREDA signed a Memorandum of Understanding with the Bank to carry out studies in specific renewable energy sectors. The study has been carried out at a cost of US $ 371,000 including a contribution of US $ 354,000 from the Bank.

Concluding Remarks

Several studies carried out have established that significant potential exists in India for Bagasse Based Co-Generation. Further, the interest shown by the Government of India, the State Governments and international funding agencies have provided the necessary thrust to encourage sugar mills to become more and more conscious for energy conservation and venture into the area of high efficiency co-generation leading to export of surplus power. As one of the largest processors of cane sugar, Indian sugar industry is on the threshold of making a visible penetration in power generation sector.

CONTRACTURAL ISSUES CONCERNING COGENERATION

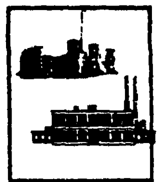
MR DAN JANTZEN
RENEWABLE ENERGY PROJECT SUPPORT OFFICE

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

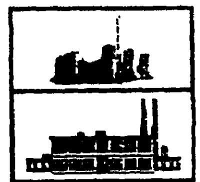
Contractural Issues Concerning Cogeneration

Dan Jantzen
Renewable Energy Project Support Office
Presentation to the
First International Cogeneration Conference in India
March 11-12, 1996

Two Ownership Patterns



Single Ownership

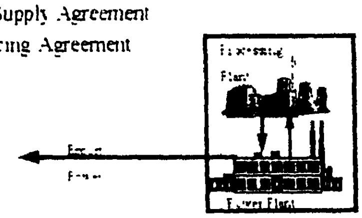


Split Ownership

Contracts Required

Single Ownership

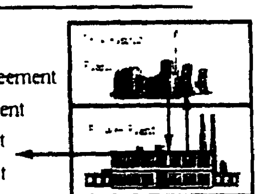
- Power Purchase Agreement
- Fuel Supply Agreement
- Financing Agreement



Contracts Required

Split Ownership

- Power Purchase Agreement
- Fuel Supply Agreement
- Financing Agreement
- Operation Agreement
- Land Purchase/Lease Agreement
- Fuel/Steam/Power Exchange Agreement



Power Purchase Agreement --Principles--

- Define the obligations of each party
- Spell out "what happens" under any circumstance which could arise

PPA -- Items to be covered

- Parties to the contract
- Term of the contract
- Terms and tariffs for power sale
- Interconnection arrangements
- Continuity of service
- Safety provisions
- Metering
- Permits and licenses
- Default & termination
- Indemnification
- Assignment
- Force Majeure
- Authority to execute
- Liability
- Conflicts
- Definitions

"Works of Art"

- Each contract is a "work of art" and no two are alike
- As experience is gained, new clauses are added to cover undefined circumstances

The International Cane Energy Network has published a compendium of 12 sugar cogeneration power sale contacts from around the world. Available from Winrock International for $500

COGENERATION IN SUGAR MILLS SOME TECHNICAL & COMMERCIAL ISSUES

MR HARISH BHARGAVA
MITCON LIMITED

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

CO-GENERATION IN SUGAR MILLS

SOME TECHNICAL & COMMERCIAL ISSUES

Harish Bhargava

Generation of exportable electricity from bagasse in sugar mills is universally accepted as desirable, economic and environment friendly The potential of this source of electricity is substantial. Co-generation projects can be implemented in a short time, at reasonable cost Since sugar mills are located in rural areas, co-generated electricity will benefit development of the neighbouring villages. Despite such significant advantages, projects for co-generation of exportable electricity in sugar mills are not coming up as they should.

For catalysing such projects, it is necessary that sugar mills, the electricity boards, financial and developmental institutions as well as the concerned ministries in the Centre and the States work together in close co-ordination to address some technical and commercial issues which are critical to the development and long term functioning of the projects.

It is for the Sugar Mills to first address the issues and then the Electricity Boards should give committed technical and commercial long-term support. The role of the Central and the State Government is to help the sugar mills and the electricity boards to come to fair and mutually beneficial arrangements, provide financial reasonable support and to frame stable and long-term policies taking the critical issues into consideration

TECHNICAL ISSUES

First, let us take up the technical issues The most important ones are

- **Improving Technical & Operating Efficiencies**
  - Cane
  - Milling
  - Process
  - Energy Systems
  - Maintenance

- **Installing Energy Efficient Equipment**
  - Steam Generation
  - Electricity Generation
  - Mill Drives
  - Process
  - Centrifugal Drives

- **Optimum Design & Configuration of Energy System for Processing and Power Generation**

- **Energy Conservation**

- **Evacuation of Surplus Power**

The level of co-generation of electricity in sugar mills can be substantially increased by the introduction of the latest technology, based on energy efficient equipment and systems for manufacturing sugar, high pressure boilers for raising steam, high efficiency turbines for generating power and implementing energy

economy measures to reduce consumption of steam and electricity in sugar mills This can result in the availability of significantly large quantity of exportable electric energy from sugar mills, in relatively short time and at economical cost.

The issues related to production of sugar are well known to the sugar mills Only the importance of optimising these for efficient co-generation of electricity needs to be fully appreciated and recognised. The Energy System Design, however, merits a close look.

Energy System Design & Optimisation:

For optimum results, it is necessary that the co-generation system is carefully designed to take full advantage of the potential in each individual sugar mill and, at the same time, meet the energy demand pattern of the region in which the sugar mill is operating. Such optimisation can be achieved through a detailed analysis, followed by integration of sugar mill operations, electric load demand pattern of the region and the future requirements.

High-efficiency Boilers & Turbines:

Boilers and turbines operating at high pressure/temperature and with high efficiency are now available in India. Boilers and turbines must be carefully selected on basis of a long-term benefit/cost analysis

There are apprehensions in the mind of potential co-generators about operating of such "hi-tech" power plants These are totally unfounded and have to be removed by upgrading the knowledge base of the potential investors With correct choice of the power plant components and proper training of the operators there need be no such fears From techno-economic considerations relevant to India, it would be desirable to standardise on boiler pressure of 63 bar, and temperature of 480°C

Water treatment is an important aspect. Make-up feed water should be of satisfactory quality and returned condensate free from contamination. Proper water treatment is necessary even for boilers operating at lower pressures of 21, 32 or 42 bar

Turbines, of course, will match the boiler pressure Depending on the Mode of operation, the turbine could be simple back pressure or with controlled extraction and/or bleed or condensing or a combination of these.

The Four Modes for Co-generation:

The scheme for maximising co-generation of electricity in sugar mills can be based on one of the following four Modes. The choice is governed by the inputs available on one hand and the pattern of additional power requirements on the other

It is important to recognise that irrespective of the choice of the Mode for co-generation, use of high-pressure boilers, high-efficiency turbines and realisation of maximum energy economy are the absolute imperatives for maximising net exportable power from any sugar mill

Mode # 1

Fuel	Only bagasse
Duration	Only during the crushing season
Steam/Power Generation	To meet process requirements
Bagasse Usage	Surplus bagasse to be disposed off
Support Fuel	None.
Type of Turbine	Back Pressure

This Mode is the one in use at all sugar mills in India.

Generating capacity and quantum of electricity produced can be maximised by operating at highest economic steam pressure and temperature considered operationally feasible, such as, 63 bar, 480°C, by reconfiguring the process requirements to achieve maximum economy in consumption of steam and power and by adopting energy conservation measures..

Maximisation of power generation can be achieved through minimum additional investment, which will also lower the cost of production of sugar.

The energy produced will vary, from time to time, with the changes in the rate of cane crushed and corresponding production of bagasse.

Mode # 2

Fuel	Only bagasse
Duration	Only during the crushing season
Steam/Power Generation	Maximum: utilising all available bagasse
Bagasse Usage	Bagasse as produced, fully consumed
Support Fuel	None.
Type of Turbine	Extraction/Condensing

In an environment of power shortage, especially if the peak time of the year of the Grid coincides with the crushing season, the SEB may like the sugar mill, to maximise power generation during the crushing season, by utilising all the bagasse as it is produced.

The energy so produced may either be sold to the SEB or wheeled to other units during the crushing season, or banked with the SEB for use within and/or outside the crushing season.

The above Mode will provide for such a requirement.

It will be necessary to use an extraction/condensing turbine, with steam in excess of the process requirements, going through the condenser.

The sizing of the condensing part of the turbine will need to be such as to handle maximum steam flow, after meeting the minimum process steam requrements

The level of energy production can be better stabilised under this Mode, if some bagasse is stored, in an intermediate storage facility, and is subsequently used during periods of low crushing rate.

Mode # 3

Fuel	Only bagasse
Duration	During the crushing season, and for a certain period beyond the crushing season.
Steam/Power Generation	To meet process requirements during the crushing season. As required and feasible, beyond the crushing season.
Bagasse Usage	Surplus bagasse to be stored and used after the crushing season.
Support Fuel	None.
Type of Turbine	Extraction/Condensing

Relevance of this Mode is under a situation in which the region where the sugar mill is operating has the peak demand period after the crushing season, say, during June - November. This Mode can also be used if the SEB requires uniform level of power supply from the sugar mill over a long period, say, 270 days in a year.

The rate of consumption of bagasse during the crushing season and of the stored bagasse during the off season will have to be regulated such that the desired level of power export can be maintained.

The sizing of the condensing part of the turbine should be based on the maximum rate at which power will be required to be generated during the off-season.

Mode # 4

Fuel	**Primary** : Bagasse **Secondary**: Agro-waste/Coal/Lignite/LSHS/Furnace Oil/ Natural Gas.
Duration	Round-the-Year
Steam/Power Generation	Maximum; more than required to meet process requirements.
Bagasse Usage	All bagasse to be used. No surplus
Support Fuel	Agro-waste, Coal, Lignite, LSHS, Furnace Oil or Natural Gas - as economically available.
Type of Turbine	Extraction/Condensing

This Mode would be the ideal choice for mills located such that a secondary fuel is available at an economic cost, with short transportation lead and high reliability of supply. The advantages of this Mode are:

- Power generation and export at a high and steady level
- Feasibility of operating the system at the maximum economic rating.
- Availability of energy to SEB throughout the year.
- Productive use of capital invested, without any idling.

Capital cost of the system will be relatively high, since additional facilities for handling of the support fuel, ash disposal and air pollution control will be necessary.

As against this, energy generated will be much more, firm and throughout the year, resulting in higher revenue. Since the capital invested will not be idle during the off-season, the incidence of the fixed cost component on the cost of generation will be lower.

Economic viability of this Mode, therefore, must be very carefully assessed

Alternative Configurations:

A number of alternative configurations of the Boiler/Turbine/Alternator system are possible. Examples are:

- Replacement of Total System.
- New High Pressure Boiler and Topping Turbine linked to Existing System
- Back Pressure, Controlled Extraction and Condensing turbines.
- Bleed for providing steam to Sulphur Burners and Centrifugals.
- High Voltage Alternator.

By judicious choice, the objective of optimising power generation and cost can be realised.

Energy Economy:

The internal consumption of energy, including that of the generated electricity must be minimised. This requires use of energy efficient equipment, energy conservation measures and elimination of wastage

Integration between the Generating Plant & the Grid:

The design and equipment specifications of the generating and inter-connecting equipment must be such as to make inter-connected operation with the Grid totally trouble-free. The generation of power should be such that the internal requirements and the needs of the SEB are met as optimally as possible.

This requires providing of the required operational flexibility at the design stage, followed by efficient and well co-ordinated operational management.

COMMERCIAL ISSUES

The basic commercial issues are:

- Evacuation and Power Supply Contracts based on Remunerative Long-term Price, Prompt and Assured Payment for Exported Power
- One Time Incentives
- Financing Support

EVACUATION & POWER SUPPLY CONTRACTS

Direct Radial Supply to End-users:

Supply to own or related units, at the same location is ideal It may also be possible to supply to other units in the immediate neighbourhood, through independent and dedicated tie-lines. Small producers of power should be allowed "Right of Way" over public roads etc., with minimum procedural formalities, and at a nominal charge.

If there are any legal hurdles blocking such arrangements, these need to be removed by amending the concerned legislation

In most cases, however, it will not be possible to evacuate all exportable power by this Mode

Sale/Purchase - Co-generators / SEB:

This arrangement is most desirable since it will ensure equitable and economic utilisation of exportable power

Long-term supply contracts entered into must be such that the interests of both the Co-generator and SEB are adequately served and protected. It should be possible for the stipulated operational requirements to be met from both the sides, without unacceptable problems arising The price must provide the Producer a reasonable return throughout the expected life of the investment At the same time, the price should be that which the SEB can afford to pay Further, the contracts should cover not only the current issues, but provide for permanent and long-term safeguards for both the parties

Wheeling:

This implies 'Real-Time' supply from the Producer to the End-User by wheeling of energy through the SEB grid Energy supplied is withdrawn at the same time, or, within a short interval of time the SEB is paid a wheeling charge for use of the transmission facilities

Under this Mode, the supply could be to:

Own Units - at the same or different location/s
Other units - at the same or different locations/s

Wheeling charges should be reasonably low, not more than 7% of the energy supplied, and should be recovered in the form of energy retained.

The price should be as mutually negotiated between Producer and the End-User based on the market forces.

Banking:

The arrangement is similar to wheeling, except that it is not 'Real Time' Energy supplied to the SEB grid may be 'banked' for use at some other time within a certain agreed period

Under this Mode also, the supply could be to

Own Units - at the same or different location/s
Other units - at the same or different locations/s.

Banking charges should be reasonably low, not more than 8% of the energy supplied, and should be recovered in the form of energy retained. The extra 1% over the Wheeling charge will compensate SEB for retaining power in the system

The price should be as mutually negotiated between Co-generator and the End-User based on the market forces..

Standardisation & Enforceability of Contracts:

It is essential that National Model contracts are designed and are made enforceable through appropriate legislation, with as simple rules and regulations as possible

A national contract prepared by MNES and DOP, in consultation with the concerned parties, could be legislated by the Parliament as a Central Act States wanting to encourage small producers of power could then enact their own legislation, based on the Central act, with such changes as may be necessary to suit situations unique to the State.

PAYMENT BY STATE ELECTRICITY BOARD

Long-term assurance of payment by SEB against amounts due, in line with the agreed contractual terms, is essential. This could be through

Irrevocable, revolving, self-replenishing letter of credit

OR

Escrow account backed by SEB bankers

Either of these instruments could be operated through the bank account in which SEB receivable are credited

FINANCING

In co-generation systems, only the incremental cost of plant, equipment and other such capital costs should be regarded as the capital expenditure for the upgrading of Co-generation facilities resulting in the availability of net exportable power

The cost of upgrading process efficiency and energy conservation can and should be separately financed For instance, in case of a sugar mill, this could be financed by the Sugar Development Fund.

The cost of upgrading co-generation systems in an existing sugar mill can be reduced by disposing off the displaced plant and equipment to new sugar mills experiencing shortage of capital funds and other interested buyers.

The financing needs and the possible funding sources are:

Feasibility Studies:

The cost of feasibility studies for small power plants could be financed by grants from development financing agencies like:

> World Bank, IFC, ADB, USAID, European Union; IDBI, ICICI, IFCI, NABARD, NCDC, MENS, IREDA, and Sugar Development Fund.

This could be under a condition that if an assisted and feasible project is not implemented by the promoter, the grant given for the feasibility study will be paid back.

Capital Investment:

Once a project is finalised for implementation, funds should be made available on soft terms as grants and/or low interest term loans with moratorium of at least two years and repayment period of 10 to 15 years

The pattern of financing could be made up from equity, debt, loans and grants. The possible sources are listed below:

Equity:

Promoters; Major Users; Equipment Suppliers
SEB
Central & State Development/Financial Institutions
Power Finance Corporation
Public Issue
IFC

Debt:

Debentures, Fixed Deposits; Bonds

Loan:

IDBI, ICICI; IFCI, NABARD, NCDC, SDF, PFC
State Financial Institutions

World Bank; IFC; ADB, UNDP; GEF, GEEP
US EXIM Bank; European Union.

Grants:

MNES, IREDA

IFC/USA/European Union/Other Governments

BOLT / BOOT DEVELOPMENT

Serious consideration should be given to encouraging competent parties to set up co-generation projects on "Build-Operate-Lease-Transfer" and "Build-Own-Operate-Transfer" basis This will enable the projects to be financed, set up and operated easily The sugar mills will benefit from acquiring valuable experience of investing in and operating such projects and ultimately own the project

REGULATIONS

Co-generators should be governed by effective, simple and absolutely essential regulations. If there are any legal hurdles blocking direct sale of electricity by a Producer to End-users, these must be removed by suitably amending the concerned legislation.

Minimum approvals should be required for setting up a small power plant, with effective, prompt and single window clearances from Central and State governments, as well as SEBs

PROMOTIONAL INCENTIVES

No subsidies should be provided for small power plants. In order to attract investment in small power plants and to offset the relatively higher capital cost of such plant, "one-time" incentives must be granted.

COGENERATION OF POWER

BY
INFRASTRUCTURE LEASING AND FINANCIAL SERVICES LTD.

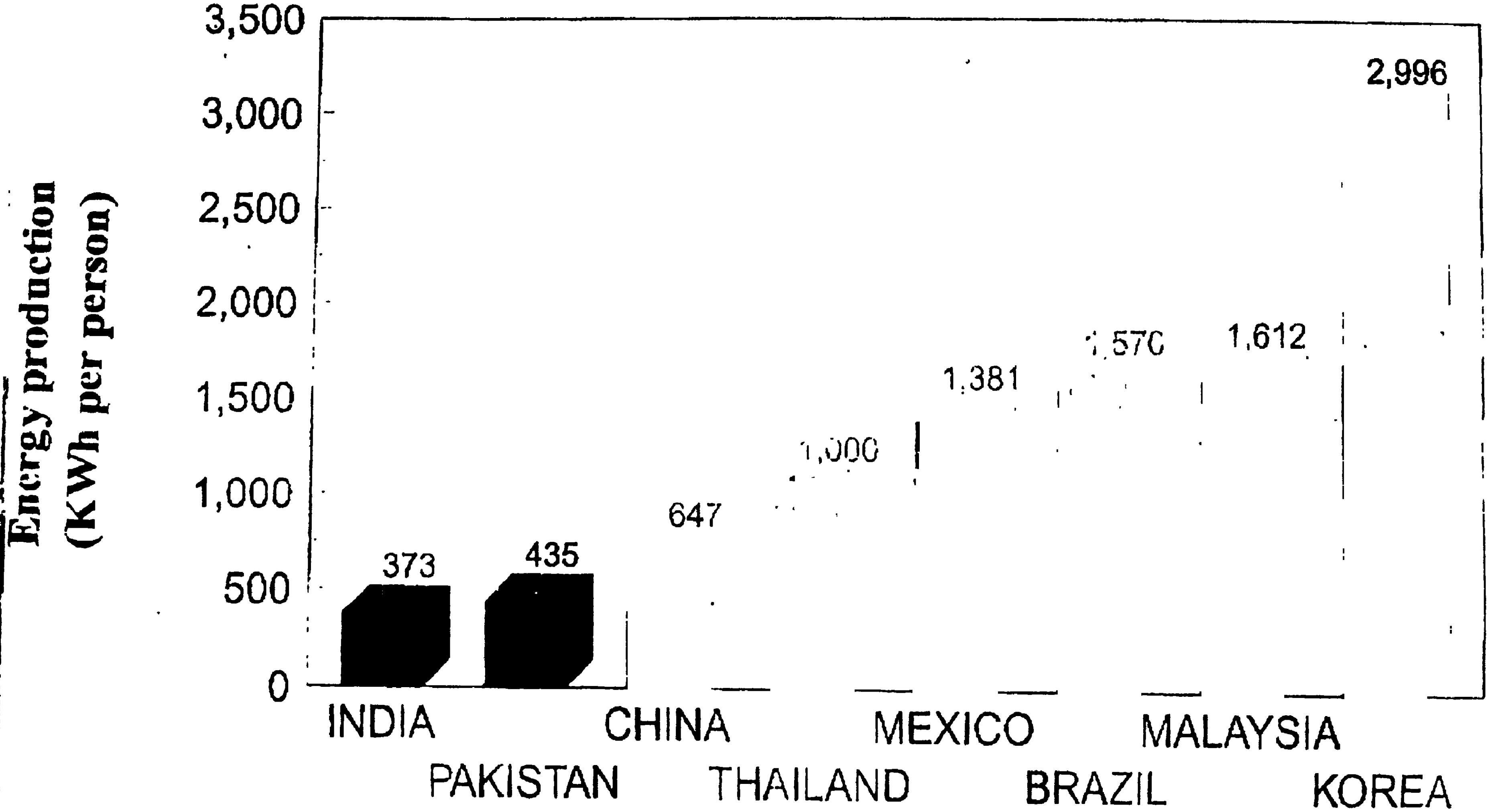
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WIDENING DEMAND-SUPPLY GAP IL&FS

- Total installed capacity : 78,900 MW; energy shortage of 9%
- Eighth plan target scaled down from 40,000 MW to around 19,000 MW due to budgetary constraints
- Total available supply : 47,200 MW
- Peak demand : 56,200 MW
- Peak demand shortage
  - Present : 17%
  - Expected by end 1997 : 20%

CRITICAL COMPARISONS

IL&FS



RECENT DEVELOPMENTS IN THE POWER SECTOR

IL&FS

- Progress : Though about 200 project proposals since inception, few projects have achieved financial close
- Transmission and Distribution has not been privatised so far
- MoU process no longer valid; competitive bidding the order of the day
- Focus shifts to delivered price
  - A number of SEBs now fixing the offtake of power at a pre-determined price from the power developer
  - Consequently, a number of power developers have reduced their capital costs, to bring down the tariff to acceptable levels

COGENERATION...A WAY OUT IL&FS

- Numerous obstacles faced by power developers in setting up new projects has led to a delay, thus worsening the power situation in the country
- The current shortfall in demand can effectively be met by the existing process plants by Cogeneration
- Cogeneration is the simultaneous generation of heat and power using exhaust and waste gases
- This power generated using cogeneration can be used for captive purposes within the plant

THE PROCESS

IL&FS

- Almost all industries need electric power as a motive force
- Some industries like textiles, paper, food processing and petrochemicals also require steam directly as an input for the process
- Cogeneration can effectively serve the industry's requirements of power and steam
- The sugar industry is most amenable to cogeneration as the by-product is bagasse, which is produced during the course of sugar production
- This bagasse is used as a raw material for generating power
- Industries like paper, cement and chemical industries have potential for power generation through cogeneration as heated waste gases are generated in the course of production

TYPES OF COGENERATION

IL&FS

- Cogenerated power can be produced in three ways :
  - <u>Topping Cycle</u>
    - Power is produced initially
    - A part of the thermal energy is used in process plants
  - <u>Bottoming Cycle</u>
    - Recovers waste heat from plant process
    - This waste heat is used to produce steam for running turbines
  - <u>Combined Cycle</u>
    - Steam is generated from waste gases exiting from turbine
    - The steam recovered is used for running turbines and generating power
    - Steam from the turbine is used directly for an industrial process

THE BENEFITS

IL&FS

- Capital Cost : A cogeneration plant is about 25% cheaper than a conventional one
- Implementation Period : A cogeneration plant can be setup and commissioned within 12-18 months
- Profitability : Payback period of 3 years, at current SEB offtake tariff rates
- Fuel Conservation : Lesser dependence on fossil fuels like coal, coupled with relatively pollution free operation

THE OBSTACLES

IL&FS

- The need for cogeneration has been increasingly felt due to the power shortage existing in the country
- Steam required for cogeneration needs to be at high pressure and temperature, necessitating investment in large, high-pressure boilers
- Most industries did not anticipate the need for installing high pressure boilers for cogeneration due to a relatively comfortable power supply from SEBs in the past
- In case the cogeneration plant is unable to consume all the power it generates, some part of power generated would have to be sold to the SEBs
- Lack of encouragement from SEBs in the form of non-competitive rates for wheeling and banking of power to high tension consumers

THE INCENTIVES

IL&FS

- **Loan** : The World Bank would fund cogeneration facilities in sugar factories in India to the tune of US$ 6 mn. Funds would be channelled though a credit line to National Development Council

- **Fiscal Advantages** :
  - Cogeneration equipment has been classified as energy saving equipment and is eligible for 100% depreciation
  - Import duties on capital equipment have been reduced

- **Subsidies** :
  - Govt of Karnataka is offering a subsidy of Rs 25 lacs per MW to cogeneration units based on bagasse. This is in addition to the existing Union Govt subsidy of Rs 70 lacs per MW
  - MNES provides a subsidy on loans sanctioned by FIs for the purchase of cogeneration equipment by sugar mills

PROGRESS MADE

IL&FS

- Changes in the policies of several states in the form of incentives offered are inducing process industries to consider this option
  - The Maharashtra Government has fixed a rate of Rs 2.25 per unit as price for offtake of cogenerated power from sugar factories producing power in excess of 4 MW
  - MSEB would hold equity upto 60% in such projects, with the sugar company having the option to buyback the equity against adjustment for sale of power
  - Two sugar co-operatives each in Maharashtra and Tamil Nadu have setup cogeneration units
  - Another 10-12 sugar co-ops in Maharashtra are envisaged to setup cogeneration units soon with a capacity of 10 MW each

COGENERATION IN SUGAR PLANTS IL&FS

- Existing sugar plants generate substantial amount of by-product in the form of bagasse during the course of sugar production
- During the sugar season, bagasse generated in the course of sugar production is sufficient to meet power generation requirements
- Excess bagasse produced during season is stored for power generation in off season
- Bagasse is also bought during season from other sugar mills for using in off-season
- Exportable Power $_{\text{Off Season}}$ > Exportable Power $_{\text{In Season}}$ since Captive Demand $_{\text{Off Season}}$ < Captive Demand $_{\text{In Season}}$
- The Power Purchase Agreement between the Sugar Company and the SEB needs to take into account the difference in exportable power during the year

PROJECT FINANCING

IL&FS

- As cogeneration plants are relatively small in size, financing is not perceived as a major problem
- Bankability of the Project would be enhanced if the sugar plant enters into water tight agreements with various entities like SEBs, equipment suppliers and O&M Contractors
- A Project Lease could be an attractive source of funding in view of 100% depreciation benefit to this sector
- Project could be domiciled in a Special Purpose Vehicle (SPV) formed for this purpose. This approach entails benefits like :
  - Ease of induction of strategic investors
  - Fiscal benefits in the form of Tax incentives u/s 80 IA
  - Escrow arrangement between the SPV and the SEB so that
    - SPV has first charge over SEB revenues
    - Lessors realise lease rentals from the SPV easily

FUTURE OF COGENERATION

- It has been estimated that all the sugar factories in India put together can generate over 2,500 MW of cogenerated power per year
- Import duties on equipment need to fall further, to attract industries in this area
- Problems with SEBs in evacuating, banking and wheeling power to demand centres need to be sorted out

ENVIRONMENTAL BENEFITS OF COGENERATION

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THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

Environmental Benefits of Cogeneration

Dr Damyant Luthra
Consultant, TERI

Cogeneration provides better resource utilisation. At the simplest level, demand for heat and electricity serviced in the co-generation mode would reduce resource consumption by a minimum of 20% in comparison with if it were independently serviced by the traditional mode. This in turn implies a proportional reduction in air, water and solid residuals discharged to the environment.

The above applies to a single user situation. Consider an industrial estate where multiple users could utilise a cogeneration unit (similar from providing a service somewhat on the lines of a common effluent treatment plant) to service multiple demands for heat and electricity. Here, resource utilisation efficiency improvements could be in the range of 50%, as existing independent units are generally oversized and therefore are operating at much lower efficiencies.

What does this imply in terms of environmental benefits? As an example, let us consider coal which is India's major energy resource. There is a significant reduction in air emissions for local and regional pollutants (particulate matter, oxides of sulphur, oxides of nitrogen, and carbon monoxide) as well as global (carbon dioxide). Apart from air emissions a major residual from coal combustion is ash (average ash content in Indian non-coking coal is about 40-50%) which requires large tracts of land for disposal. Roughly speaking, a 1000MW plant produces 4000 tonnes of ash in a week which requires an area of land equivalent to a football field 10 feet in depth. As land is a prime resource, any reduction in ash disposal would imply tremendous economic savings. This is especially true in urban/semi-urban locations where land is scarce and competes for alternative uses. Furthermore, there are possibilities for leaching of toxic pollutants from ashponds into the neighbouring groundwater systems, overflow of ash to surface water- bodies, and dust pollution from dried ash ponds.

To summarise, cogeneration offers tremendous environmental benefits through better resource utilisation and should be encouraged in a large way.

STEAM TURBINE OPTIONS FOR OPTIMIZING CO-GENERATION APPLICATIONS

MR C N NATH
BHARAT HEAVY ELECTRICALS LIMITED

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

STEAM TURBINE OPTIONS
FOR
OPTIMIZING CO-GENERATION APPLICATIONS

BY : C.N.NATH, SR.MANAGER, TURBINE DESIGNS, BHEL-HYD-32.

SYNOPSIS : The application of steam turbines for Co-generation, namely, meeting power and steam requirements simultaneously, is well known. Depending on pressure level or levels desired, a number of solutions are available to the system designer. As the individual design parameters do change considerably, depending on the type of industry and the process adopted, specific analysis of the thermodynamic configuration, operating range desired and control aspects, are essential for arriving at an optimum solution. The method of realizing process steam is to be examined critically in order to obtain good range of operation, good efficiencies without loosing cost effectiveness. Having thus chosen the system configuration, the required steam turbine is selected and built with proven and reliable components based on B.H.E.L's modular concept. The adaptability and flexibility of this design concept permits the designer to achieve high conversion efficiencies with excellent reliability.

INTRODUCTION : In the context of today's energy scenario, especially in India, wherein, energy costs are increasing, availability of power from grid is not assured and gap is widening between demand and supply of installed capacities, it is imperative for new industries to plan for captive power generation. For industries where requirement of steam for process also exists, like in Fertilizer, paper, petrochemical, sugar industries, co-generation of power & process steam is the obvious choice.

As an example, a typical application of co-generating a given heat & power separately and in co-generation mode are compared at fig.1. Separate generation as at A uses a straight condensing turbine for generation of power & a low pressure boiler for generation of steam required for meeting process heat. B is the co-generation mode to meet same requirements. The primary fuel requirement in mode B is 15.3 % less. The benefit accrues in co-generation due to the integration of steam generation at high parameters and reduction of heat rejection to atmosphere as the base Carnot cycle efficiency improves. Further, gains are realised by careful study of the thermodynamic layout of system, and the use of state of the art concept for building of turbine.

BASIC EFFICIENCY: The basic efficiency for a thermodynamic cycle is defined as below.

$$ETA = 1 - \frac{T2}{T1}$$

Where ETA : is the Carnot cycle efficiency, which is the highest thermodynamic efficiency possible when operating between two temperature levels.

T1 : The temperature at which heat addition to the cycle takes place.

T2 : The temperature at which heat rejection from the cycle takes place.

It is evident from the equation that higher temperature at inlet & lower at exhaust results in higher efficiency. This is why the system designer always looks for higher parameters, costs

permitting. Even though in the 50's there have been plants with very high parameters, of the order of 300 ata & 600°C, the operational, and maintenance difficulties have restricted these to the level of 140 bar /540°C for industrial applications. Those problems are largely overcome today due to metallurgical developments in steel for high temperature use, advanced computer techniques for thermal stress analysis etc. This brings in the option for the enterprising client of higher temperature solutions, with the resulting incremental gain in efficiency. Recently at BHEL we have designed and put into service a back pressure turbine for TCL Mithapur with inlet temperature of 570°C at 106 bar. Here the incremental gain in efficiency was justifiable with a pay back period of about 3 years for the difference in investment. For the lower temperature T2, the limitations occur due to the ambient conditions available at a given site. Lower the ambient temperature, lower is the cooling water temperature considered for design,resulting in lower vacuum in condenser.For the process industry, where heating steam requirements exists, the quantity of steam to condenser can be reduced by taking extractions from the turbine. The limiting case is the back pressure turbine where no condenser is involved and efficiencies of the order of 90% are possible.

PROCESS STEAM DEMANDS : The process steam demands are very specific for a given industry and the capacity of the plant envisaged. The steam flow, pressure and temperature levels are dictated by the equipment at the consumption point. Hence the pressure levels required from turbine are fixed. Table 1 gives the typical range of pressure levels required to be met by turbine for extraction & exhaust steam.

TABLE : 1

INDUSTRY	PROCESS STEAM PRESSURE
FERTILIZER/ PETROCHEMICAL	40 ATA HP STEAM
	25 ATA MP STEAM
	5 ATA LP STEAM
PAPER/FIBER	10 ATA HP STEAM
	5 ATA LP STEAM
SUGAR	1.5 TO 2.5 ATA.

INTEGRATED APPROACH : The endeavor of the system designer is to integrate the process steam demands and power demands - either electrical power or power for mechanical drive application - in the best possible manner, in a steam turbine, keeping in view the consideration for high basic efficiency. The ideal solution is a back pressure turbine (see Fig.2). If the steam demand is such that, less power is produced than is required, a condensing portion will have to be used. This results in lowering of efficiency but results in attaining the desired balance of power & steam requirements. This solution is achieved by using a condensing turbine with extraction of steam from the turbine casing at an appropriate level.

Options for extraction : The extraction steam from turbine can be met in these two ways:

1. Extraction of steam at the desired pressure level and throttling the steam flow to the condensing part of the turbine in a throttle valve for controlling the pressure (See fig.3). This is known as `controlled extraction.

2. Extraction of steam at a higher pressure from turbine and throttling the same to desired pressures level in the extraction line (See Fig.4). This is known as externally controlled extraction.

In the first case the steam turbine is required to be divided into HP & LP parts by using an intermediate gland for isolation and LP control valves of appropriate size mounted on the turbine. Figure-5 shows the typical cross section of such a turbine.

In the second case, the turbine is a straight condensing turbine with gap in between stages at appropriate location and corresponding opening in the casing for tapping extraction steam. As pressure is controlled in extraction line with the help of pressure control valve, no turbine mounted valves are necessary. Fig.6 shows the cross section of such a machine.

The choice of the solution adopted depends on the quantum of steam required to be extracted. Generally, where quantities of steam to condenser is less, controlled extraction is the choice and where quantities of steam to process is less, external controls for extraction is the choice.

As an example, the case of a steam turbine with steam parameters as at table 2 is considered for analysis.

TABLE -2

Steam Parameters for analysis		
Inlet Pressure	:	65 ATA.
Inlet Temperature	:	480 DEG C.
Inlet Steam flow	:	9Kgs/Sec.
Extraction Pressure	:	5.0 ATA.
Exhaust Pressure	:	0.1 ATA.

For a given inlet steam flow, the extraction quantity is varied from 10% to 50% . The corresponding power generation in a turbine with internal control (i.e. throttling flow to condenser) and a turbine with external control (throttling flow to process) are compared in Fig.7.

In the case of external control, the pressure at tapping point on turbine casing is considered to be 10 ata, so as to allow extraction of steam at 50% part load operation also, that is a turndown of 50% . It can be seen from the curves in Fig.7 that upto 13% of inlet quantity as extraction, external control is better compared to internal control. (The point of intersection of curves A and B). If the turn down is reduced to 10% , then the cut off point shifts to 39% of inlet flow. (the point of intersection of curves A and C).

[illegible] of extraction flow to inlet flow [illegible] control needs to be examined [illegible] envisaged will play a deciding [illegible] extraction steam is taken to meet [illegible] normal requirement is small, [illegible] Fig 3 will have to be chosen. [illegible] less efficient than the other choice.

[illegible] turn down is specified for meeting [illegible] extraction machine will have [illegible] of the given application at [illegible]. However, in this case, a solution for greater turn down with [illegible] is possible by adopting what is known as a wander extraction.

Wander Extraction For achieving greater turn-down when extraction steam flows are not very high with reference to inlet flow, a straight condensing turbine is used with two or more tapping points for extraction. The pressure at the lowest extraction point is decided to meet a turn down ratio of 10% (say). Then, for operation below 90% load pressure at this point will not

be adequate for meeting the process pressure and the steam will be tapped from the next extraction point upstream (See.Fig.8.). This transfer of extraction tap off from one point to another can be done smoothly using microprocessor based wander control. A typical application of this solution was successfully adopted at FEDO, Cochin for a 10 MW. extraction turbine supplied by BHEL. Adopting uncontrolled wander controlled extraction turbines will result in simpler construction, lower costs, in addition to gain in efficiency at lower turn-down ratios.

TURBINE CONSTRUCTION. Having the steam parameters, power, range of operation specified by the user, it becomes the task of the turbine manufacturer to select and build a turbine to achieve best conversion efficiency and with high reliability. Towards achieving this objective, the modular system based on building block principle is used by BHEL. The basic system adopted from SIEMENS OF GERMANY envisages the use of standard and proven modules with total flexibility in configuring the thermodynamic flow path.

The standard modules comprise of inlet section, bearing housing, bearings, exhaust sections, stop & governing valves, servomotors, last stage blades etc. Fig.5 depicts the general concept involved. The appropriate [illegible] of front, rear and middle portions are [illegible] turbine optimum for a specific application [illegible] For each machine configured, the [illegible] computer programs for optimizing the [illegible] components. Subsequent to the [illegible] analysis is done, again using computer [illegible] of simulating various modes of operation. Correction [illegible] is done where required to result in a stable [illegible]

CONCLUSION : By careful choice of parameters,analysis of requirements of flows, range of operation, it is possible to optimise any system configuration for making best use of energy expended. In this endeavor, all the parties, namely, the user, the system designer and the equipment manufacturer have a role to play.

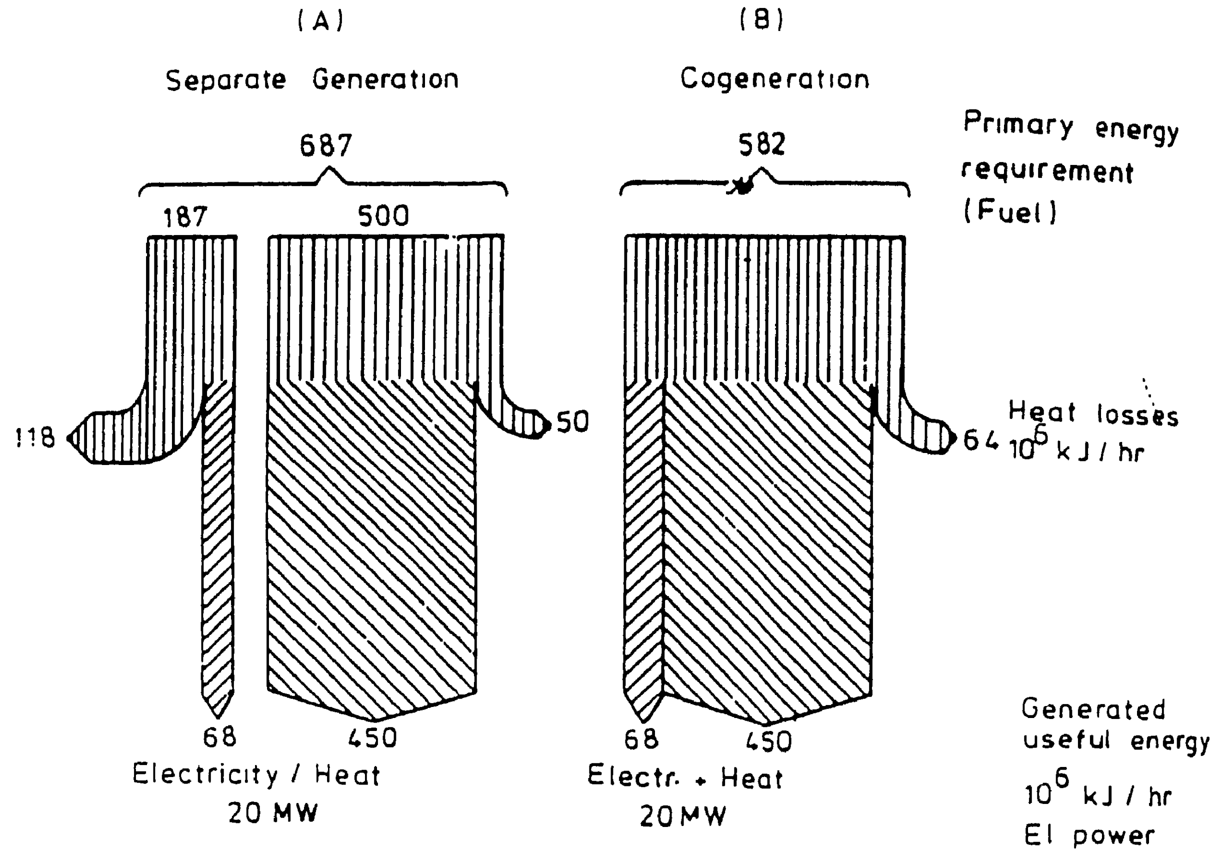
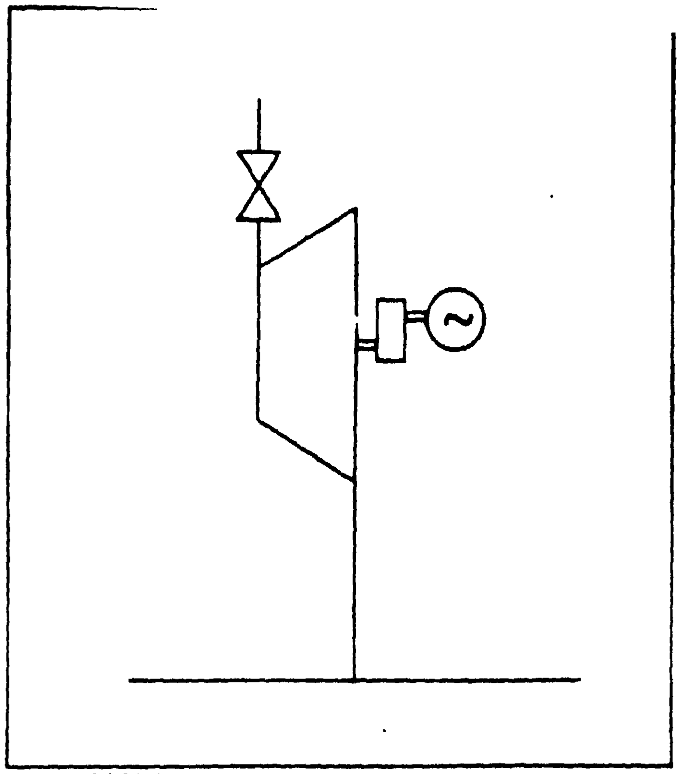
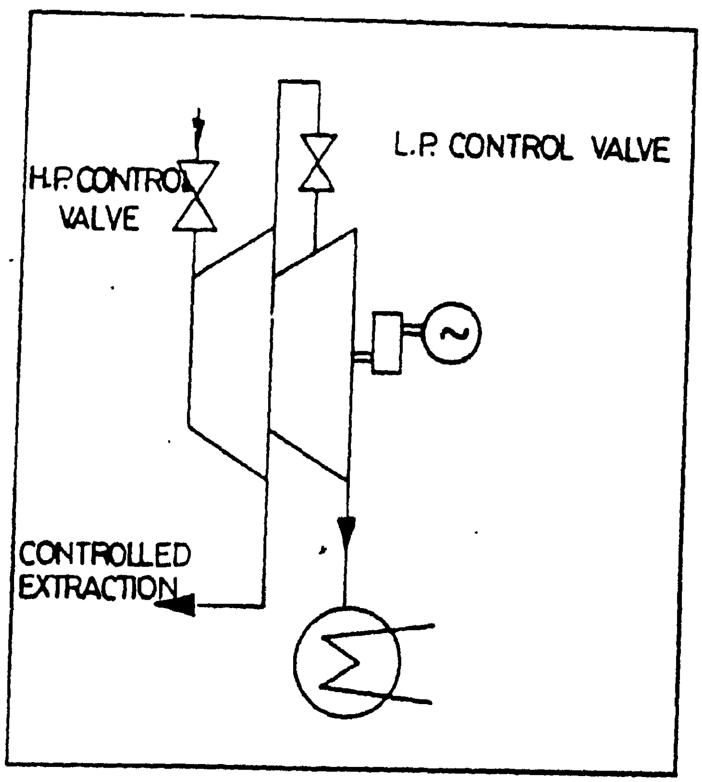


Fig. 1 Comparison of the primary energy (fuel) requirement for the generation of 450×10^6 kJ / hr and 20 MW electrical power (A) with production in separate plants and (B) with cogeneration.



BACK PRESSURE
TURBINE

FIG: 2



EXTRACTION
CONDENSING TURBINE

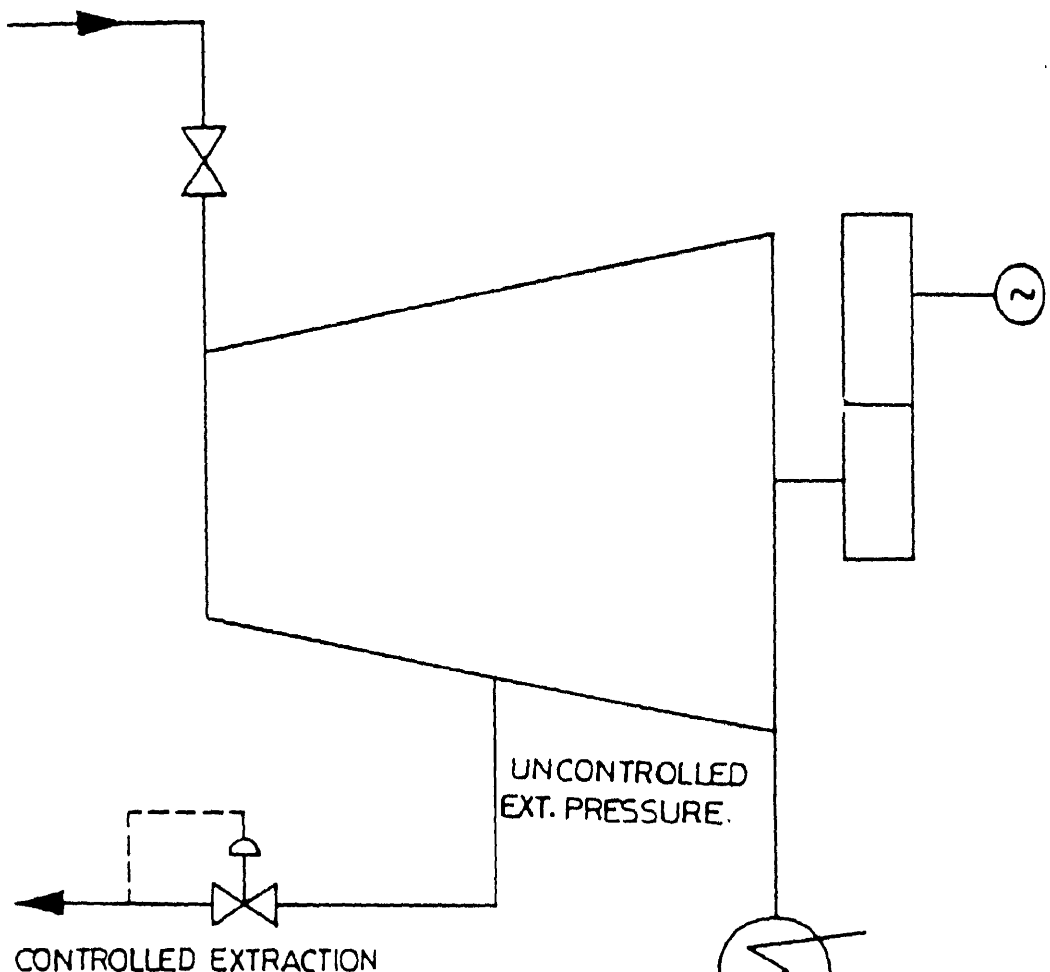


FIG4: CONDENSING TURBINE WITH EXTERNAL CONTROL FOR EXTRACTION

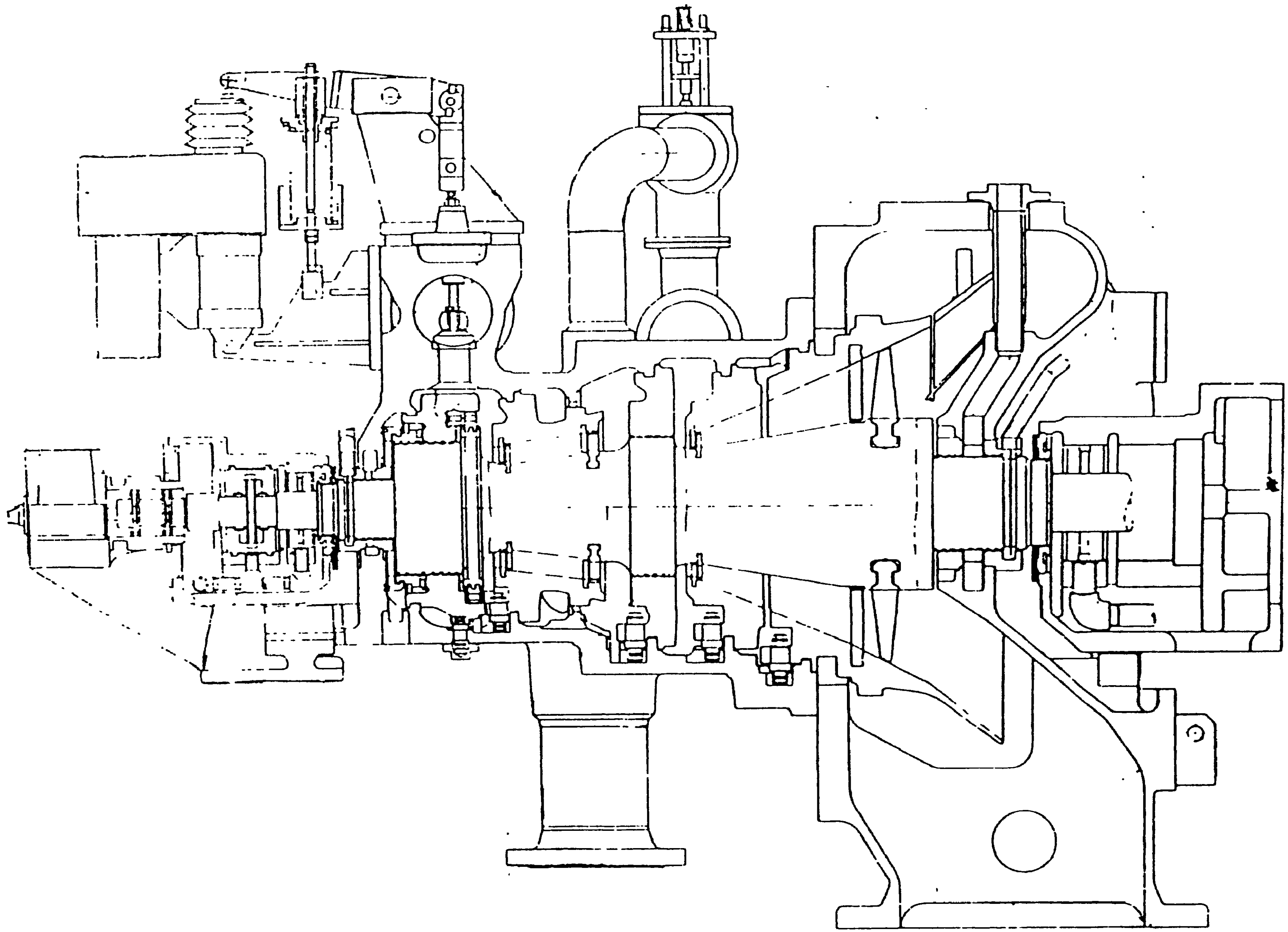
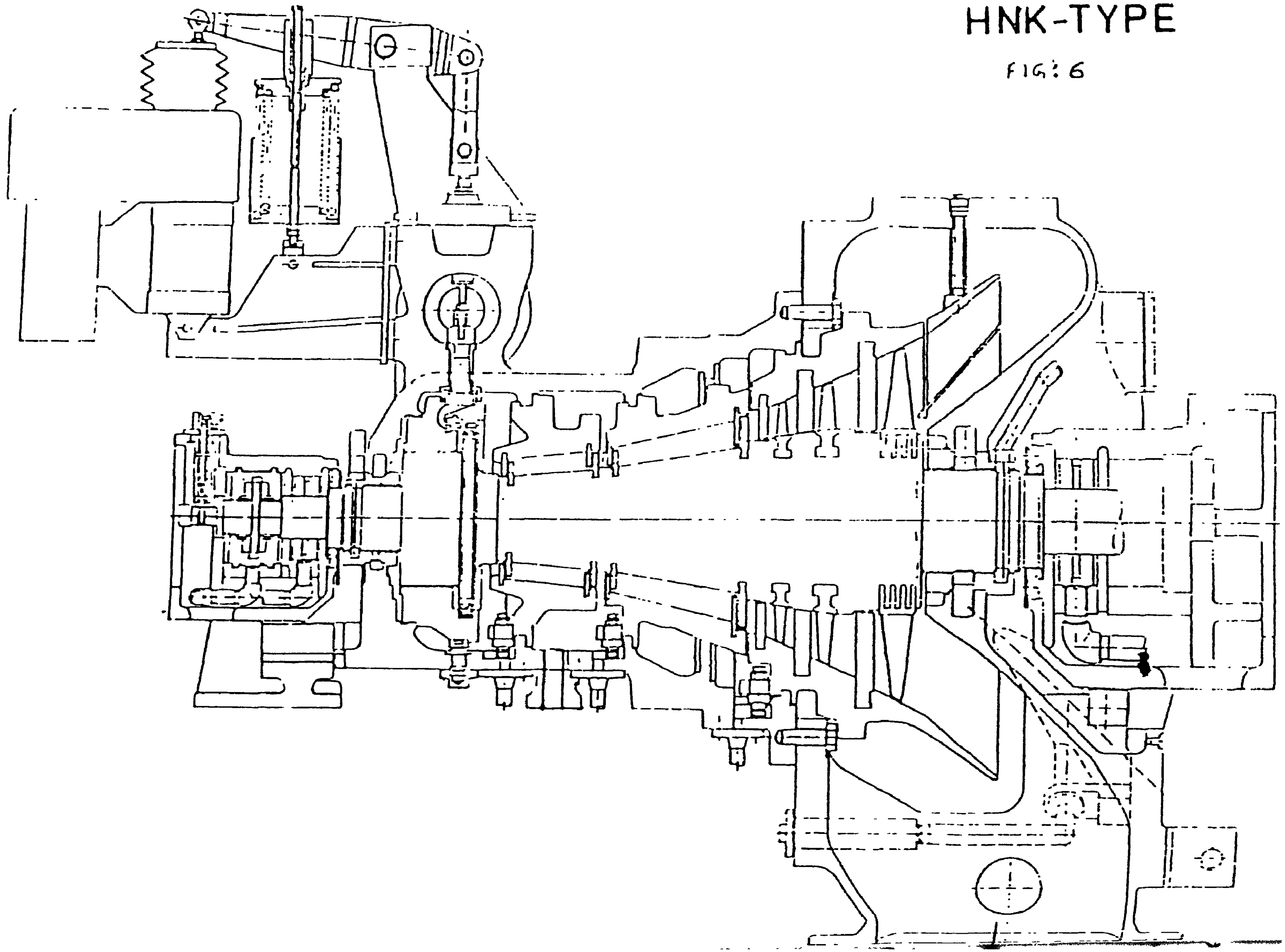


FIG. 5 Cross section of single CONTROLLED extraction turbine

TURBINE CROSS SECTION

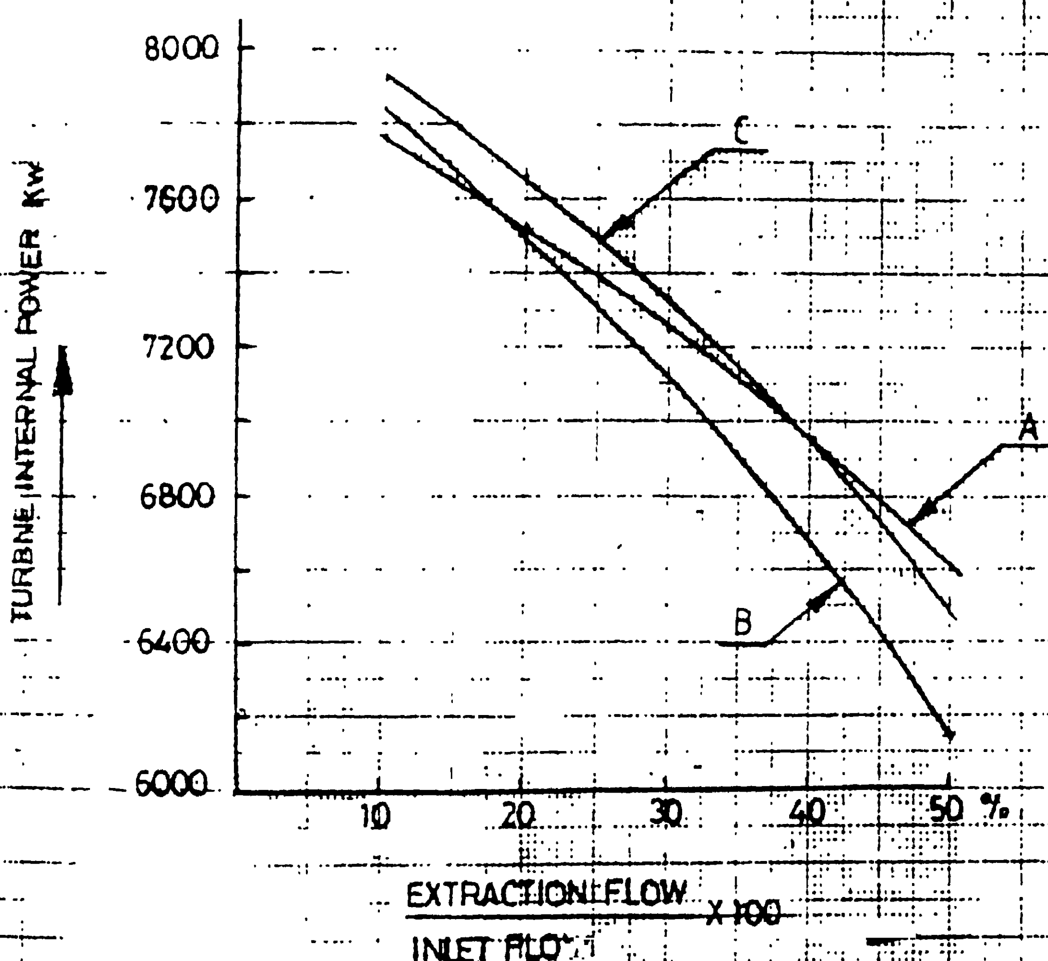
HNK-TYPE

FIG: 6



OF STEAM EXTRACTION PRESSURE

FIGURE. 7



CURVE A: TURBINE WITH CONTROLLED EXTRACTION

CURVE B: TURBINE WITH EXTERNAL CONTROLLED EXTRACTION
TURN DOWN RATIO: 50%

CURVE C: TURBINE WITH EXTERNAL CONTROLLED EXTRACTION
TURN DOWN RATIO: 10%

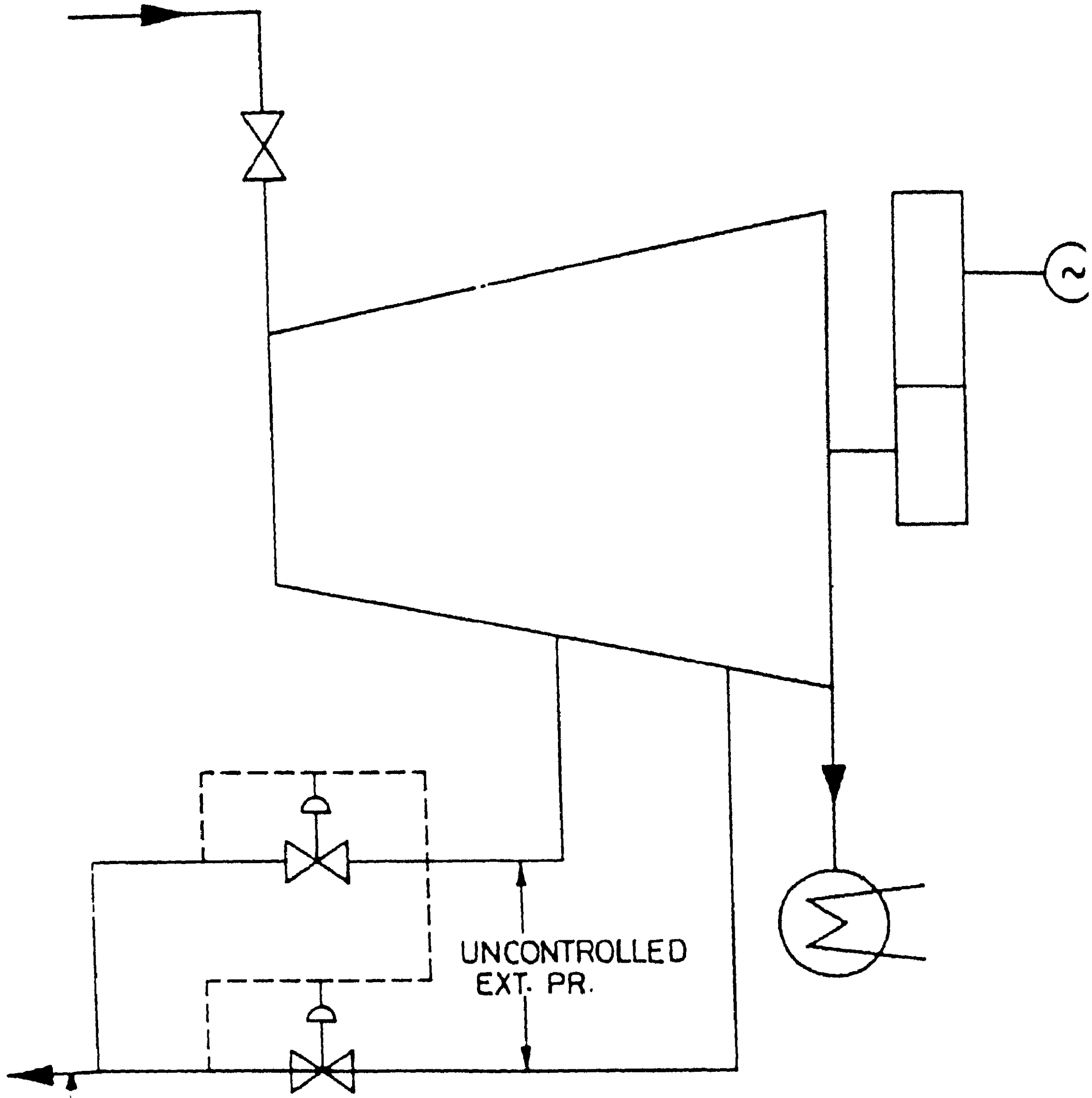


FIG8: WANDER CONTROLLED EXTRACTION

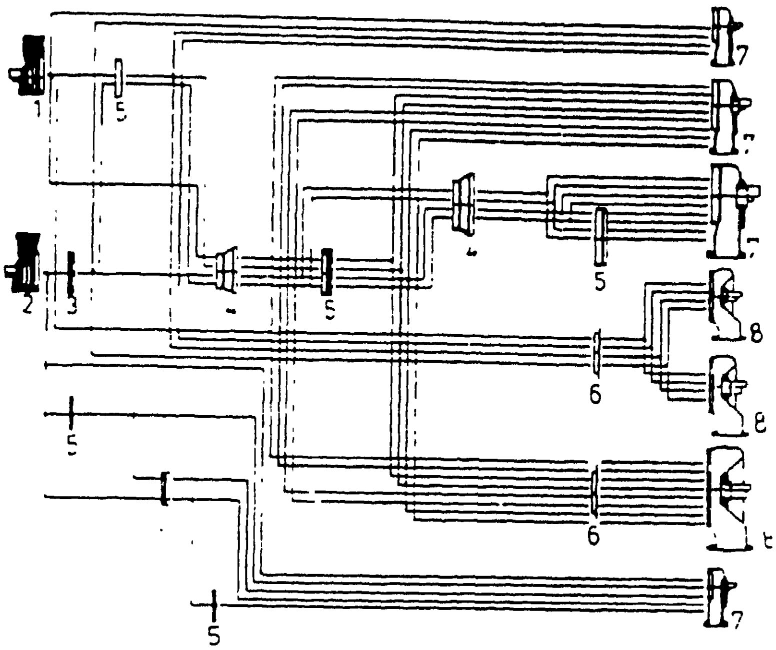


Fig 9 BUILDING BLOCK SYSTEM

1	Admission section N	6	Flange section
2	Admission section H	7	Exhaust section backpressure turbine
3	Reducing section		
4	Transition section	8	Exhaust section condensing turbine
5	Extension section		

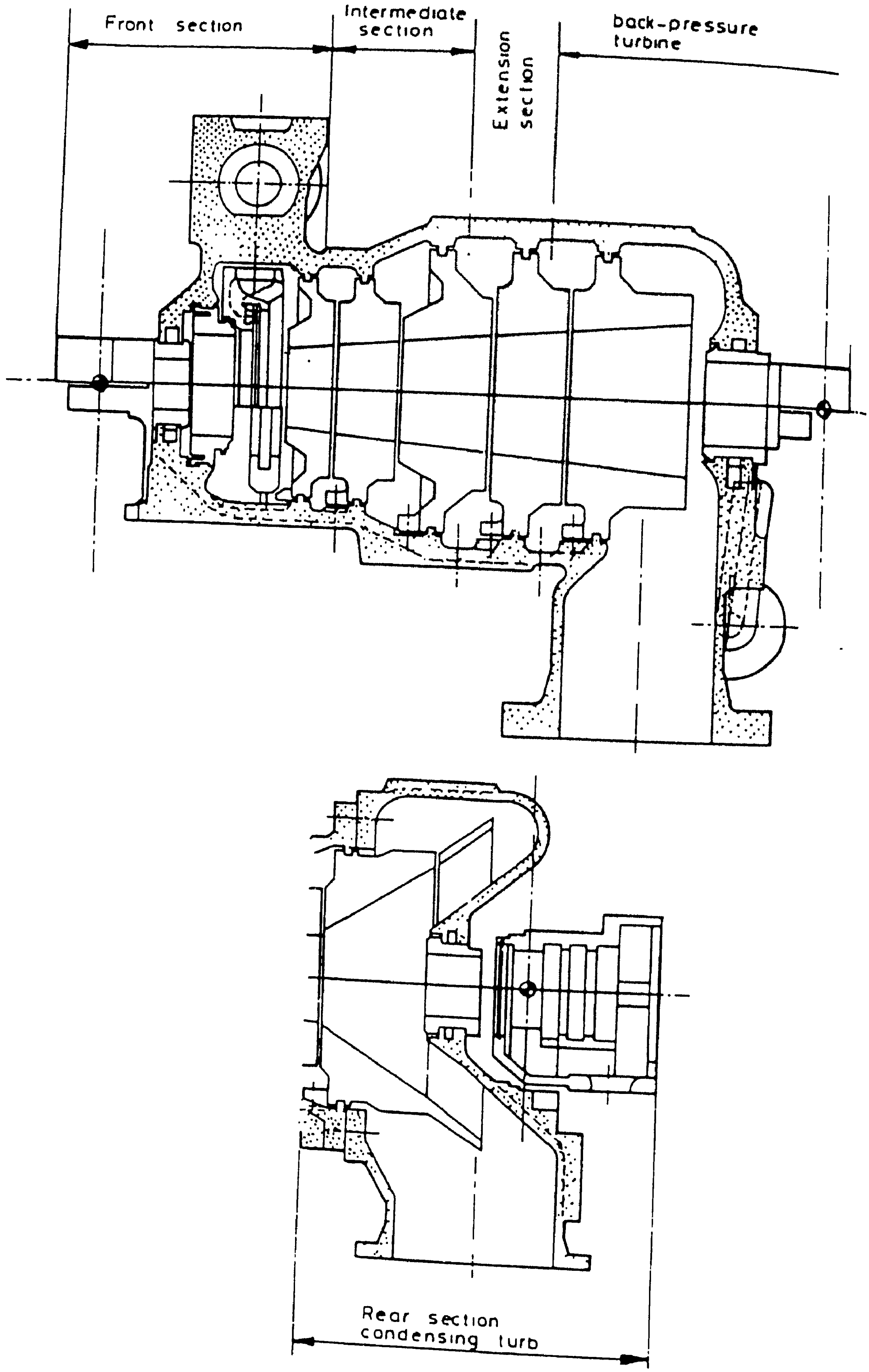


Fig.10 Sectional construction of industrial steam turbines

GAS TURBINE BURNING NAPHTHA - SPECIAL FEATURES

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Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

GAS TURBINE BURNING NAPHTHA - SPECIAL FEATURES

Satish Pandey, K.K. Sharma, Avtar Singh & Rod Oglesby.

In India with rapid industrial development in the last decade and limited energy reserves there has been increasing quest of using alternative cheaper fuel for power generation. Naphtha has been recognised as one of the cheaper fuels for power generation in Indian industry using gas turbines. This paper does not cover availability, procedure for allocation etc. of Naphtha.

It is known that Naphtha is cracked to produce Ethylene or Gasolene which demand premium rate in the market. This process however is used only in some of the advanced countries. In India requirement of cracked products have been limited and availability of Naphtha at low cost was analysed for its suitability as a Gas turbine fuel for Power generation.

Though there are good number of gas turbine installations using Naphtha as fuel, these plants are however normally in capacities of above 10 MW and use Naphtha as back up fuel except a few.

In India Triveni Engineering is supplying CHP plants under 10 MW capacity using gas turbines with Naphtha as fuel. These turbines are manufactured by European Gas Turbines Ltd, UK - GEC Alsthom Group - Triveni's collaborators. Some of the installations under execution by Triveni are designed to fire Naphtha as main fuel and HSD/Kerosene as back up fuels.

This paper discusses features that are specially incorporated to ensure a reliable and safe operation of plant when using Naphtha as fuel. Following system/auxiliaries of gas turbine have received special considerations:

1. Fuel forwarding & boosting system
2. Fuel distribution system
3. Ventilation with Fire & Gas System
4. Drain and vent system.
5. Purge system

FUEL FORWARDING & BOOSTING SYSTEM

When designing the fuel system the following two typical characteristics of Naphtha have been very specially looked into:

1. Low flash point (less than 23 Deg.C) and high vapour pressure.

2. Low viscosity (less than 0.5 CST at 30 Deg.C).

1. <u>Low flash point and high vapour pressure:</u>

This makes Naphtha a highly volatile and inflammable liquid and following major events need to be avoided w.r.t. Gas Turbines.

- During start and stop sequences there is likelyhood of some Naphtha trapping in pipeline resulting in to "vapour locking".

- Any Naphtha vapour and air should be removed from system piping because formation of a mixture of atmospheric air (oxygen) and Naphtha is very explosive.

- Removal of unburnt Naphtha from the system when gas turbine shuts down/during abortive starts.

The above facts led to extensive study and discussions with some of the users of Naphtha based CHP plants and it was considered necessary to use HSD for startup/stop sequences. Fig. 1 shows basic scheme.

There is no denial to the fact that Gas Turbine can be started and stopped on Naphtha and it has already been tested in some of the existing GT installations, where Naphtha is being used as a back up fuel, however this practice is not entirely safe and use of HSD is absolutely essential for want of safety, due to above reasons.

2. Low Viscosity:

Naphtha provides almost nil lubrication effect and is highly corrosive in nature resulting into excessive wear of high pressure boosting pumps. Traditionally HITEK is added to Naphtha to provide lubricity as this enhances pump life. However using HITEK is suitable only for systems where Naphtha is used less frequently and is used as an alternative fuel. Further the high cost of HITEK discourages its use. In view of this due care has been given to consider fuel system components, like pumps and valves to be suitable for very low viscosity fluid with special emphasis on type of seals

which are more prone to wear. While Naphtha forwarding pumps - Low pressure pump - are a centrifugal type, the Naphtha boosting pump - High pressure pumps - are reciprocating type with their separate lube oil system. These pumps conform to API 610 with material of construction to handle very low/nil viscosity liquid like Naphtha.

Further as per observations and recommendations of High pressure, system is designed to blend 1% HSD in to Naphtha to ensure a better/long pump life. This provides an economically effective solution in view of already existing HSD circuit and avoids use of HITEK.

FUEL DISTRIBUTION SYSTEM

While using Naphtha, the rotating components in the fuel system which need lubrication and which are maintenance prone need to be restricted.Two design approaches are available to design the fuel distribution system:

1. Conventional mechanical flow division of fuel.

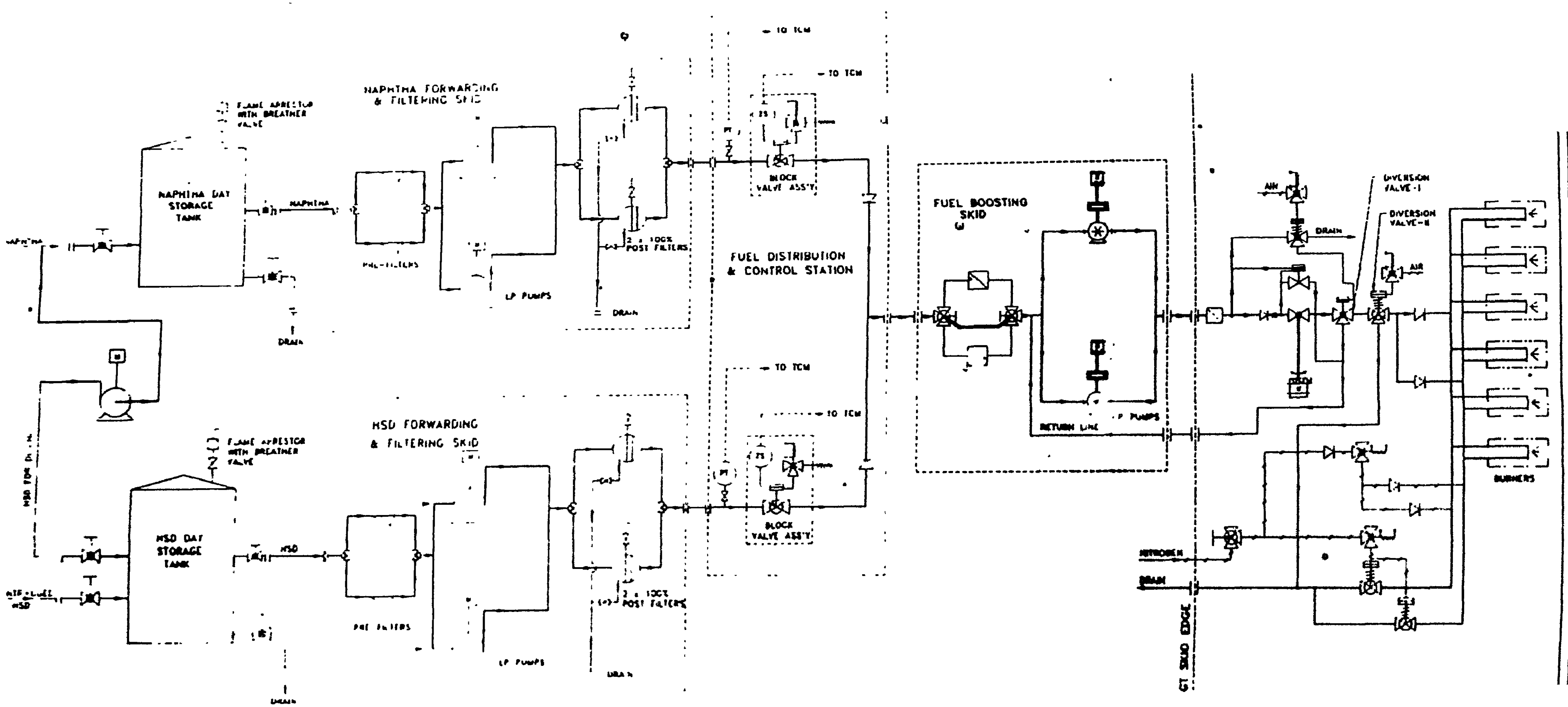
2. The pressure flow division.

Convensional mechanical flow division of fuel uses positive displacement gear pumps which pump the liquid fuel to the flow divider. Flow divider uses gear pumps driven by a single shaft. The flow divider further pressurises the fuel and directs it to each combustor. The number of gear pumps is equal to the number of cumbustors.

Studies conducted by leading gas turbine manufacturers indicate that a low lubricity fuel like Naphtha reduces life of the flow divider and requires frequent maintenance/replacement. In view of this a pressure flow division system is preferable and is easier to operate with small gas turbines.

The gas turbines manufactured by EGT, U.K. employ only one fuel boosting pump and further fuel distribution in to the combustion chambers (can-annular type) affected by the resistance offered by fuel nozzles. Further each combustor is fitted with duplex liquid fuel nozzle which maintains high fuel line pressure even at the time of starting when small quantity of fuel is required.

A typical fuel distribution system is shown in fig. 1.



NAPHTHA DAY STORAGE TANK
FLAME ARRESTOR WITH BREATHER VALVE
NAPHTHA FORWARDING & FILTERING SKID
LP PUMPS
2 x 100% POST FILTERS
DRAIN
TO TCM
BLOCK VALVE ASS'Y
FUEL DISTRIBUTION & CONTROL STATION
FUEL BOOSTING SKID
RETURN LINE
HSD DAY STORAGE TANK
HSD FORWARDING & FILTERING SKID
PRE FILTERS
HSD
GT SKID EDGE
NITROGEN
AIR
DIVERSION VALVE-I
DIVERSION VALVE-II
BURNERS

FIG. 1.

VENTILATION WITH FIRE & GAS SYSTEM:

In European classification Naphtha falls under Group II A, while in the USA it is grouped in class I Group D - which are same as for natural gas.

The auto-Ignition temperature of natural gas approaches 600 Deg.C. whereas that of Naphtha is 290 Deg.C.

The flamable limits of Naphtha in air are very low compared to natural gas (Naphtha LEL 0.9% to UEL 6% by volume Natural gas LEL 3.8% to UEL 17%). This means Natural gas has a wider flamable range and therefore higher concentration must be reached before it becomes explosive. Naphtha on the other hand becomes explosive in very small concentration and hence an adequate ventilation system is required. The appropriate temperature classification for Naphtha fuel as per specification IS:5571-1979 is T 3 which restricts maximum surface temperature to 200 Deg.C. The accessories and gas turbine compartments would be classified as Class I division II Group D as per NEC standards and Group II A, as per European Classification (EEC CENELEC EN 50014), which are same as for natural gas.

Due to same classification for Gas fuel and Naphtha, the enclosure ventilation design philosophy is common to both. The preferred reference is always the Institute of Petroleum "Area Classification Code for Petroleum Installations" (bearing part 15 of the IP model code of safe practice in the Petroleum Industry). Borne out of experience of many GT installations, the IP codes now include sections specifically related to GT layout.

The consideration for designing the gas turbine enclosure ventilation is whether Gas Turbine in enclosure is located in safe area or hazardous area? And as such enclosures are normally located in safe (non hazardous area) it is depressurised in relation to the area outside it.

The underlying philosophy is always that in the event of structural or any other failure, the atmospheric air shall flow from safe area to the hazardous area and not vice versa.

While fire and gas system philosophy similar to that of natural gas is followed, emphasis is given on selection of suitable Naphtha vapour detectors to sense presence of Naphtha vapour with LEL of even 0.9%.

DRAIN & VENT SYSTEM

Owing to high flammable characteristics of Naphtha followings are considered while designing, installing and operating vent & drain in the gas turbine which may contain Naphtha either in the liquid or vapour form.

i) Flammability .- Sources of ignition may include the following:-

a) Electrical - sparks or arcs may occur across gaps between current carrying contacts or through static electricity discharge.

b) Naked lights - smoking, hot repair work, exposed incandescent material

c) Internal combustion engines - spark ignition systems and hot spots on exhausts.

d) Spontaneous combustion - pyrophoric materials, leaks of hydrocarbons above spontaneous ignition temperature.

e) Frictional ignition - impact, or rubbing, when using power operated tools, or mechanical failure of rotating equipment.

f) High temperature surfaces - high temperature steam lines, or other hot surfaces whose temperature exceeds the spontaneous ignition temperature.

THE ABOVE MUST ALL BE CONSIDERED IN A NAPHTHA HANDLING FACILITY.

ii) Toxicity - The principle hazard in the storage and handling of Naphtha is in the Flammability, but it must be noted that a concentration of 2% in air is likely to rapidly cause death.

In the case of highly aromatic Naphtha, armomatic hydrocarbons can be readily absorbed into the body via inhalation or skin absorption. These liquids cause local defatting and irritation of the skin and this may lead to blistering and dermatitis The appropriate precautions must therefore be taken in handling the material and in maintaining pumps, tanks, valves etc. It is recommended that appropriate clothing, i.e. gloves and overalls etc. be worn during these activities.

iii) Electrical and Sparking Hazards

a) All electrical equipment used in the vicinity should be of flameproof design i.e. a minimum rating of zone II.

b) Any maintenance tools (i.e. hammers, wrenches etc.) should be designed not to generate sparking when in use.

c) Earthed conductive pipe should be installed, bonded between flanges.

d) It is recommended any free water which is present should be regularly drained from tankage.

e) Drain tank shells should be earthed. In the case of a floating cover in a fixed roof tank, this is often of polyurethane construction (of low conductivity). It is essential that all metal attachments to this cover are connected to the shell by flexible bonding straps. The resistance to earth from any point on the cover should not exceed 10 ohms.

f) Clothing can increase electrostatic potential such that an incendive spark may discharge to an earthed conductor. Antistatic shoes should be worn, but it should be appreciated that these could be ineffective if the wearer were walking on low conductive material.

g) High velocity steam cleaning should be avoided even when the nozzle is earthed. Tank cleaning is permitted with high pressure water jets only - after gas freeing or inerting.

iv) Valves - Ball valves are preferred and should be antistatic and firesafe design having stainless steel body and trim with glass reinforced PTFE seats and seals. An electric earthing strap is required between stem and body.

v) Naphtha Vapour Hazards - As Naphtha vapour is heavier than air any leakage of fuel from flange joints, connections etc. will generate vapours which will tend to accumulate at any low points. Hence measures to remove this vapour or eliminate low points should be taken. I.e. pipes should be either run above ground level or if in trenches these should be sand filled. Any low points which cannot be eliminated should be provided with means to draw off the vapour to a safe area where it can be flared off at low level. Normally a vapour extractor is provided close to the base of GT base frame which draws Naphtha vapour from inside the base frame - in case of any Naphtha leakage inside the enclosure - collected at the bottom, to a safe distance.

vi) All Naphtha drains from the system should be taken out from individual equipment drains to a safe distance and terminated/routed back to the day storage tank.

vii) Auto Drain Valve:

While vent & drain requirement based on above considerations are provided an additional drain is provided in the exhaust ducting to remove any liquid fuel which collects in the exhaust ducting after an aborted start.

For this purpose an auto drain valve is provided which is operated by air from delivery stage of gas generator. The valve will be closed when the turbine is running and open to drain when the turbine is stopped.

PURGE SYSTEM:

Use of Naphtha as fuel calls for special purging requirement such as:

1. Purging with HSD during start & stop.

2. Purging with Nitrogen after shut down.

1. Purging With HSD:

Fig. 1 can be referred for explanation of purge system.

When a start sequence is initiated using one of the soft keys on the control panel the HSD fuel forwarding pump (low pressure pump) receives a start permissive. On availability of HSD at a predetermined pressure the block valve opens and signal is passed for starting of high pressure boosting pump along with closing of liquid fuel drain valves, thereby filling the liquid fuel spill line.

Further following sequence takes place:

1. Diversion valve I opens.

2. Throttle valve opens to permit a small amount of HSD approx. 10 litres per min. to flow through the system for a preset time.

3. Division valve I closes.

4. The drain valves open & drain the system.

5. A signal is passed to low & high pressure fuel pumps to stop diesel supply.

6. Throttle valve shall retur- -o its closed position.

Purging With Nitrogen:

HSD purging is done only upto diversion valve II. However after stop sequence it is necessary to remove any unburnt liquid fuel from the combustors Normally while standard practice is to use compressed air for evacuation of any liquid fuel/HSD or its vapour. It is not safe however to use air with Naphtha fuel as it may quickly produce mixture of oxygen and Naphtha vapours under hot atmosphere, which is very explosive.

Owing to above consideration it is a safe practice to use an inert gas like nitrogen for purging of combustors.

In brief once a gas turbine is designed to operate on Naphtha fuel, special care needs to be taken. While Naphth is dangerous to handle in Gas Turbine if precautions are not taken, it is friendly, if safety procedures are adhered to.

NOTE: The paper considers system configuration and detail for a gas turbine operating on liquid fuel only. The philosophy and system details could be different for a Bifuel/Dual fuel gas turbines or when Naphtha is considered as a backup fuel

INNOVATIVE COGENERATION SCHEMES FOR FERTILIZER, REFINERY AND PROCESS PLANTS

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Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

INNOVATIVE COGENERATION SCHEMES FOR FERTILIZER, REFINERY AND PROCESS PLANTS

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March 11th, 1996

Abstract

Cogeneration is usually the most economical way of producing electric power as well as heat for process plants Indian Industry is increasingly looking towards captive power generation for uninterrupted and reliable supply This coupled with significant heat requirements, often as steam, has created added emphasis for cogeneration schemes

The steam and power requirements of each industry are unique Careful considerations are to be given to the quantity as well as quality of steam alongwith the power requirements while the system is being engineered The parameters to be taken into account while evolving the cogeneration scheme for specific applications are discussed The design features that are to be incorporated for optimal and reliable performance are elucidated

The discussions are adequately supported by three case studies The first deals with a gas turbine based cogeneration system for a fertilizer plant where unique design features have been incorporated to ensure constant high quality steam supply under different operating requirements In the second case, cogeneration scheme for a refinery plant based on unusual and difficult fuel is illustrated The last case describes how the necessities of a chemical process are addressed to arrive at optimum configuration

Finally some of the special analysis techniques required to be developed for design and supply of systems for such diverse applications are also dealt with

1 Introduction

The power sector is assuming more and more importance in the Indian scenario Especially the captive and cogeneration concepts are becoming more innovative in arriving

at cost effective solutions to the steam and power needs This makes it desirable to share the design experience across the industry in order to increase general awareness of the existing capabilities and experience This would increase the total knowledge available in the industry in addition to providing help in the assessment of what is possible. This paper is an attempt to share our experience in the area of combined cycle cogeneration plants.

For the design of a cogeneration plant and the various unit equipments in it, today's designer can make use of a host of design techniques and a variety of software. Yet, given the vast spectrum of design possibilities, the virtue of a design depends mainly upon the expertise of the designer This expertise is largely enriched through his experience with similar plants One more reason for the importance of this experience is that each situation is *unique* in respect of its demands and design parameters, and the designer has to concentrate on those aspects much more than the general aspects in order to achieve a good design It is also possible to capitalize on the unique features of the situation to get a very economical design

This paper discusses various aspects involved in the design of a cogeneration process based mainly on the particular demands and parameters of the system, as opposed to the general demands Therefore innovative deviations from the conventional designs are emphasized The paper presents three case studies highlighting design considerations vastly different from each other, which are dictated by the unique demands of the processes.

2 Design Considerations

The design of a cogeneration plant may involve many aspects which cannot be provided by one type of tool The use of multiple tools for analysing the key aspects in the cogeneration plant allows the designer to improve his visualization of the plant *a priori* and thus assist him in making good assessment of various design choices and innovating the conventional designs This section discusses the different design considerations

2.1 The Process Requirements

The process steam requirement at the battery point and the power requirement are factors which influence sizing of various equipments. Different combinations of steam and power requirements may be required at different points of time, resulting in a steam-power envelope within which satisfactory operation of the plant is expected The designer should also know the weightages given to each of these requirements Using these specifications, the skeleton design and sizing of the unit equipment are arrived at through heat and mass balance

2.2 System Performance at Design Conditions

This step represents the macro scale analysis of the system at the design point At design conditions, the system should satisfy all the constraints imposed upon it by the process requirements, metallurgical requirements, safety requirements and corrosion prevention While satisfying these constraints, the system should be optimally sized at the design conditions Usually special purpose steady state flowsheet simulators are used for this purpose

2.3 System Performance at Extreme Conditions

This is a macro scale analysis at the extreme conditions of operation expected to occur The system constraints mentioned above should be satisfied under these conditions too Also, the system should not show unacceptable performance deterioration.

2.4 Dynamic Response

The system startup and shutdown operation is best analysed with the aid of its dynamic simulation The startup or shutdown of various unit equipments in the system in synchronization with others is utmost essential For example, the gas turbines can be started up very fast, but the heat recovery steam generator (HRSG) has more thermal inertia Even if it were designed for a less thermal inertia, the pressure gradients in the steam drum change quite fast resulting in a large thermal stress which implies fatigue Also, the control system design and performance analysis can be done with the dynamic analysis For example, during HRSG startup, the most crucial aspects are monitoring the drum levels due to the *swell* effect when the liquid water in the tubes is expelled by the first vapour phase formed, and the monitoring the pressure gradients in the steam drum mentioned above

The dynamic simulation is not as straightforward as the steady state simulation, and the model validity should be ascertained for the entire range of plant operation. Very often, good tools for dynamic simulation are not available or accessible and the designer is forced to rely heavily on his past experience to visualize the dynamic response of the system

2.5 System Operability

In this step, it is ensured that the system operation is as desired Various issues considered at this stage include

- Startup process
- Shutdown process
- System maintenance
- Accessibilities of individual components
- Manual override over the control system
- Bypass lines, valves, dampers provisions

2.6 Fluid Flow Analysis

The geometry of the exchanger is very important to allow uniform distribution of the fluid flow. More often than not, the sudden curves, bends or impediments in the fluid flow path result in the fluid flow distribution which is very much away from the expected one. The maldistribution of flow of fluid outside heat transfer tubes or that in the gas flow near burners in an HRSG cause substantial drop in performance of the corresponding equipments. This affects the overall plant in general The detection of this maldistribution is possible through the fluid flow analysis by finite element techniques carried out at *key locations* in the plant. The gas velocity vectors in the inlet zone of an assisted circulation type HRSG are shown in figure 1

The design considerations discussed above give rise to a number of innovations in the plant design. These innovations may vary from case to case To strengthen this point, in the next sections three case studies have been taken up which are representative of different industries where cogeneration plants were installed One would appreciate that the design requirements and constraints are very much different from each other and have given rise to entirely different perspectives to the evolution of design

3 Case Study 1: Fertilizer Plant

The first case study presents the case of a fertilizer plant which employs a cogeneration plant There are two gas turbines connected to separate HRSG units having supplementary fuel firing The high pressure process steam requirement is critical for all compressor drives. Therefore, apart from these HRSG units, a service boiler is also provided

A unique need of this plant is wide variation in the power and steam demands The plant is required to deliver any combination of high/low power and high/low flowrate of process steam of desired specifications This poses a challenge from the control system design point of view. This problem can be best addressed by having two fuel firings in an HRSG unit, as opposed to one The amount of fuel fired closer to the steam exit is controlled by the steam temperature requirements, whereas the amount of fuel fired at an intermediate location in the HRSG is controlled by the steam flowrate requirements. Apart from meeting metallurgical concern, this arrangement provides effective control of steam flowrate and quality. Good control over steam quality eliminates the need of attemperation, which implies good thermal efficiency and good quality of steam. However, this modification results in increase in the size of the boiler due to decrease in the temperature differential in the hot and cold streams On the other hand, lower temperature differentials also mean smaller exergy losses.

One more speciality of design in this power plant is the elimination of the gas bypass system Therefore, HRSG is required to have a quick startup to match that of the gas turbine This means that the complete power plant starts up quite fast without losing

energy through the bypass stack In addition, maintenance is greatly reduced for this scheme because of elimination of moving parts in the diverter dampers

Assisted circulation type of boilers have been used These boilers employ small diameter tubes in which it is easier to achieve desired flow pattern The recirculation ratios are also small in this type of equipment, which decreases the pump and piping costs considerably

4 Case Study 2: Petrochemical Plant

This case study is being presented to demonstrate the application of heavy viscous oils as fuels in the boiler In a typical refinery, these oils are available from other process units, and one can save a great deal on the fuel cost if they can be fired in the boiler and used for the production of steam Again, the various oils are not to be mixed with each other due to their chemistry or high viscosities The usage of such *bad* fuels is always a difficult problem In this particular case study plant, four such fuels are used In addition to them, a fifth fuel -- LDO -- is used during startup

When a switchover from one fuel to another fuel is intended, to avoid their mixing, the boiler is operated on LDO for some time after the first fuel and before the next fuel Thus, LDO acts also as a switchover fuel

While LDO could be atomized in air owing to its low atomization temperature, the other four fuels can be atomized only by steam This leads to a complicated burner design Hot steam flows in the innermost tubular region in the burner. The fuel oil flows in the annular region surrounding it The oil gets atomized through small holes at the specially designed tip of the burner before getting ignited

Since there is a considerable difference in viscosities of the LDO and other fuels, the diameter of holes at the burner tips for atomizing LDO stream is smaller than that for other fuels Therefore, at the time of switchover from some fuel to LDO or from LDO to some other fuel, the burners have to be shut off and taken out for interchanging their tips

Another aspect is the high Vanadium content in these *bad* fuels which leads to hot corrosion at temperatures above 550°C The hot corrosion is due to the deposition of vanadate compounds which have a melting point in this temperature range To take care of this problem, adequate quantity of MgO powder is added to the fuel in a stirred tank vessel before it is passed on to burners This leads to formation of vanadates which have very high melting points and thus hot corrosion is avoided

To increase the thermal efficiency of the boiler, the air is preheated by the exhaust flue gas after the economiser in an air preheater Where the tube wall temperature in the air preheater becomes lower than the dew point of the flue gas, condensation of flue gas compounds on the tube surface leads to cold corrosion problem To take care of this, the

air is heated before entering the air preheater by steam in another heat exchanger, so that the tube wall temperature is always maintained above the dew point of the flue gas

5 Case Study 3: Process Plant

This case study relates to a chemical plant where a combined cycle cogeneration module has been put up in order to satisfy the requirements of process steam as well as generation of power The system had to be designed for two situations

- open cycle operation of gas turbine
- the complete combined cycle plant operational

The former mode had to be considered essentially for the first year of plant operation when the steam turbine would not be in service yet Diverter dampers are used to divert the gas flow to a bypass stack and isolate the HRSG

There are two gas turbines, each connected to one dual pressure HRSG unit. This arrangement ensures that the steam is available to the process even when one HRSG is not operational The heat available in the gas is quite high compared to the requirement of the process steam, thereby making the option of additional power generation in steam turbine attractive The high heat content in the gas also means that supplementary firing is not required in HRSG

The process requirement is for LP steam The HRSG is designed to generate HP steam of desired specifications and IP steam of intermediate specifications The HP steam is used for generating power in steam turbine A large part of the IP steam is used in the deaerator and surplus steam is mixed with the turbine extraction steam to be used as process steam Steam generation in the HP circuit depends upon the *sliding* pressure of the HRSG-steam turbne system The mixing of turbine extraction steam of low pressure and the IP steam is found to be a better alternative to generating LP steam as per the requirements of the process

Though the HRSG-steam turbine system operates under sliding pressure mode, the steam pressure is regulated so that it does not fall below a certain value This ensures satisfactory operation of the HRSG

The HRSG design ensures that the attemperation of the superheated steam in the boiler is very low at design load Higher attemperation implies higher loss in thermal efficiency of the boiler as well as less quality of the steam since water is directly added to it. At the same time, a small amount of attemperation is useful for a tight control over the boiler outlet steam superheat This small quantity of attemperation is provided between two superheater coils which is a better option than providing attemperation only after both the coils because of higher thermal efficiency

6 Conclusion

The design of a cogeneration plant needs expertise based mainly upon the experience of the designer. The complete design procedure involves various considerations including sizing, steady state and dynamic simulations, system operability and fluid flow behaviour. Each of these requires appropriate application of multiple design tools. The innovations that could be carried out based on the particular needs of the industry have been illustrated with the help of three case studies taken from three different industries. The case studies highlight the diverse needs of different industries and their influence on the plant design.

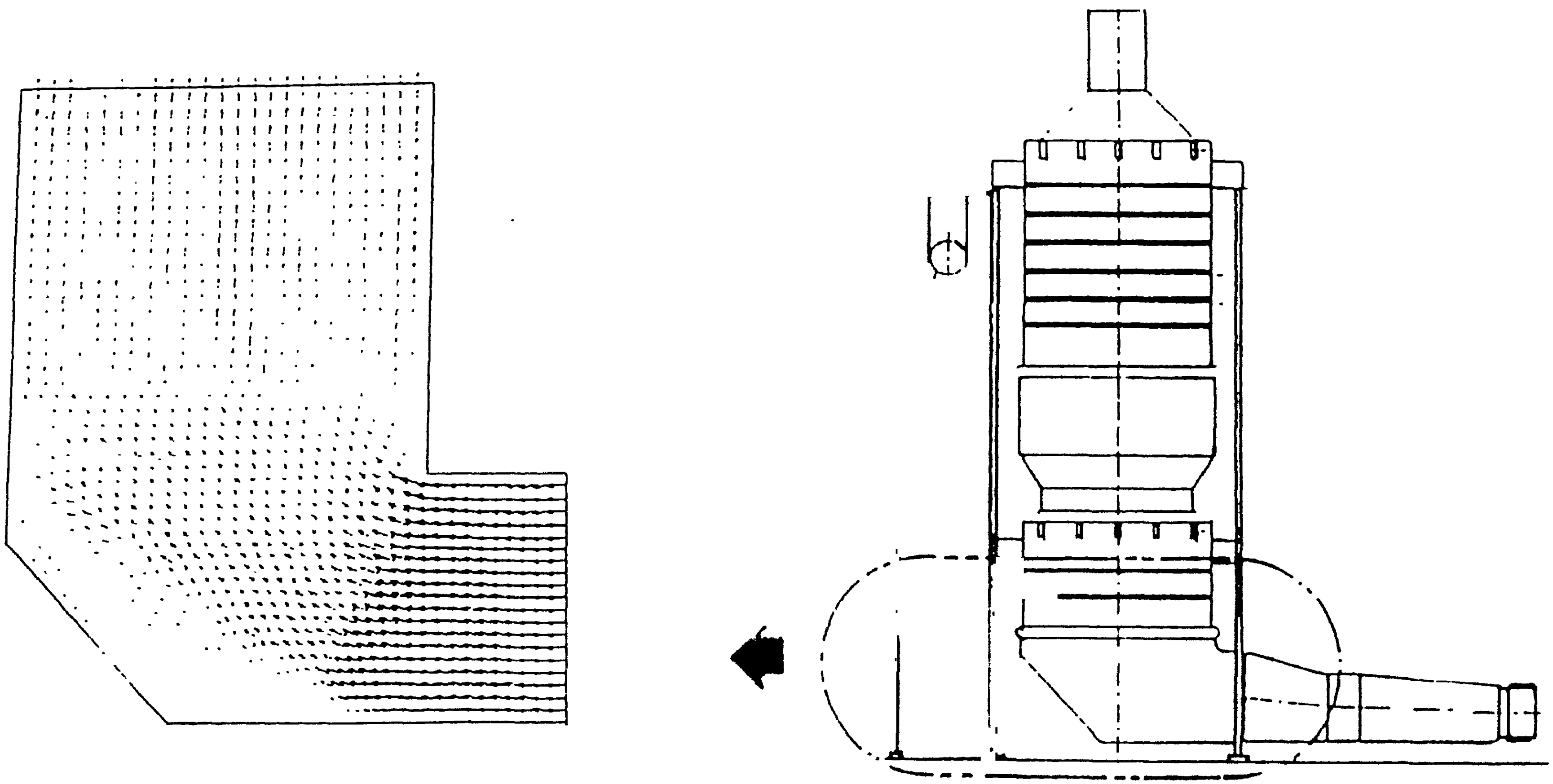


FIGURE 1 : GAS VELOCITY VECTORS AT THE INLET OF AN HRSG DETERMINED BY A FINITE ELEMENT SOFTWARE

HIGH PRESSURE BOILERS FOR CO-GENERATION USING FOSSIL FUELS

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HIGH PRESSURE BOILERS FOR CO-GENERATION USING FOSSIL FUELS

By

R KAMARAJ T BALAKRISHNAN S SHANMUGAM

Introduction

Co-generation in India during yesteryears has been restricted to meeting the on-site heat demand of the process and generation of electrical energy for captive consumption thereby reducing dependence on grid power in Sugar, Rice mills, Paper, Textiles, Chemical, Fertilisers, Petrochemicals, Steel Industries, etc,.

In the recent past,to meet the increasing power demand and with a view to efficiently utilise available power generating potential, Government of India is encouraging Industries engaged in co-generation to export surplus power to the grid. This has led to a demand of boilers with higher capacity,higher steam pressure and temperature.

BHEL's Capability

Process industries,employing Co-generation are in need of boilers with widely varying capacity, pressure and temperature, making use of the locally available fuels.

Bharat Heavy Electricals Limited (BHEL) is engaged in design, manufacture, supply, installation and services of Boilers of wide spectrum covering utility and industrial applications.

BHEL with its wide range of boiler designs, has met the Co-generation requirement of the industries in a large scale. During the last thirty year since its inception, BHEL has supplied more than 250 boilers for various Industries for Co-generation, Captive and Process needs. The boilers are designed to fire a variety of fuels - fossil fuels such as coal, oil and gas; industrial by-product process waste gases such as Carbon Monoxide gas, Blast furnace gas, Coke oven gas, etc.,

BHEL has the capability to engineer and supply a wide range of boilers tailer made to meet the requirements of Co-generation industries (such as unit capacity, fuel characteristics,space requirement etc.,) as can be seen from the table below.

Boiler type	Max.Steam generation capacity(t / hr)	Fuel type
Package boilers(VP)	180	Oil/Gas
VU60	360	Oil/gas
VU40	500	Coal,Oil,Gas
VU40S	125	Coal,bagasse, Wood.
VU60S	80	Coal,Bagasse, Wood

The above Boilers are Bi-drum Boilers suitable for steam parameters of 110 Kg/Cm² and 540°C (except Stoker fired Units).
Single drum Boiler design will be adopted for still higher pressures.

Salient features of BHEL boilers

* Fully welded waterwall construction.
* Seamless steel tubes for waterwalls,superheaters,boiler banks,economisers.
* Special corrosion resistant materials for air heaters and gas ducts.
* Modular boiler design resulting in lesser erection time.
* Stringent quality control both at shop and site.
* Excellent after sales service.

Special design features of Co-generation boilers

Co-generation demands the boilers to be suitable for widely varying operating conditions; BHEL boilers have built in features for meeting these duty conditions. Some of these are listed below:

* Wide range of temperature control (large boiler turn down).

  One of the prime requirement of Co-generation plant is to generate steam with rated temperature over a wide load. BHEL Boilers are designed to supply the rated steam temperature over wide load range, in some cases down to 25% load.

* Multi-fuel firing.

  Firing of variety of fuels either independently or in combination offers maximum flexibility to use industrial byproducts.

  Most of the BHEL Units are designed for firing multi-fuels like coal, oil and / or process gases such as blast furnace gas, coke oven gas, etc., either in combination or independently.

* Firing system

  Burners to minimise emission of combustion pollutants like NOx, Carbon Monoxide etc,.

* Capability to meet wide fluctuation in steam demand.

  Bi-drum Boiler with large Boiler banks having a lot of water holding capacity is capable of meeting the load fluctuation with ease.

* Import steam superheating.

  Superheating of import steam from other sources at different temperature levels, is unique to process industries.

  For such requirements, BHEL can offer designs with dedicated superheater to superheat the import steam.Alternatively designs facilitate a mixture of import steam and generated steam superheating to the rated temperature.

* Export steam from boiler.

  Some of the industries need high pressure saturated steam in addition to superheated steam.Under such condition, boiler can be designed to supply saturated steam from steam drum.

* Drum internals.

  Efficient drum internals ensure high steam quality as demanded by critical process and steam turbine.

* Super heater attemperation.

  Steam purity is an important parameter which will affect the process as well as operation of the steam turbine. Steam temperature control by spraying the feedwater is a normal practice. However, if the feedwater quality is poor, then mixing the feedwater with steam will directly affect the steam purity. Under such cases, saturated steam tapped of from drum is condensed and used for spray. Yet another method is cooling the superheated steam by non mixing type surface attemperator,thereby avoiding contamination by mixing with feed water.

* Feed water heating.

  While designing the Unit for different fuels, (say coal and oil), feedwater temperature entering the economiser has a bearing on the corrosion in economiser coils. However raising the feed water temperature to the higher level, demanded by the worst fuel,may not be economical always,as high feed water temperature affects the heat transfer in economiser while firing other fuel also. By providing the drum coil heater in the boiler circuit (i.e., a separate feedwater heating coil installed in drum) to heat the incoming feed water before entering the economiser. By this arrangement the feed water temperature can be varied to the desired level depending on the fuel fired.

* Pollution control.

  Efficient dust collecting equipment (Electro Static Precipitator) with sophisticated control system to reduce the emission levels to meet stringent pollution control requirement.BHEL has designed and supplied dust collecting system with an emission level as low as 50 mg per normal cubic metre.

* Controls and Instrumentation to ensure smooth and safe operation of the boiler.

* Provision for quick startup.

  Most of the process industries employing Co-generation needs steam supply uninterruptedly. In case, the operating Boiler faces any difficulty in generation, the stand-by Boiler has to come into operation at the earliest. To meet such emergency condition BHEL has designed hot stand-by system which will bring the stand-by Boiler to the full rating with minimum time.

Recent trends in Co-generation

One of the major industries with substantial potential for Co-generation is Sugar Industry. An assessment made by a committee constituted by Government of India indicates that there is a potential for generating surplus power to the tune of 3500 MW in this sector alone.

In recent times, due to the encouragement and incentives offered by Government of India for Captive Power generation, Sugar industries are planning in a big way to go in for Co-generation employing high pressure steam cycles.

BHEL has risen to the occasion to meet the co-generation requirement of Sugar Industries and are currently executing bagasse/lignite fired boilers of generating capacity 70 t/h at 65 kg/cm^2 (g), 485°C.

Fluidised bed combustion boilers for Co-generation

During the past two decades the Fluidised bed combustion boilers with their advantages, are emerging as an alternate to the boilers based on other technologies for steam generation. BHEL began investigating various aspects of the FBC process in the mid-70's, and has become one of the technological leaders among the manufacturers of FBC boilers.

BHEL has a collaboration agreement with Lurgi Lentjes Babcock (LLB), Germany, for circulating fluidised bed Boilers. A 175 T/h. circulating fluidised bed Boiler firing high ash coal is being supplied to a Paper Mill. 2 x 125MW CFBC Boilers burning lignite are under execution. BHEL offers CFBC Boilers for utility and Industries.

Waste heat recovery boilers for Co-generation

Co-generation in petrochemicals and oil refineries normally goes with either oil/gas or both as fuels due to the availability of the same. However rising cost of these prime fuels have led to a greater emphasis on higher overall cycle efficiency, maximum heat recovery, lesser payback periods, less capital cost etc., Gas/liquid fuel based Co-generation system are gaining importance and wider acceptance in the above context.

Waste heat recovery boilers play a very important role in the combined cycle Co-generation plants by recovering the sensible heat from Gas turbine exhaust, Diesel engine exhaust and sponge iron plants. BHEL, till date, has supplied more than 70 such waste heat recovery boilers to various Industries.

Conclusion

The requirements on boilers for Co-generation application for each process industry is unique due to specific requirement of the particular industry. The various design aspects,functional/operational feasibilities of BHEL boilers offer various alternatives for the industries.Today BHEL boilers are well established for Co-generation requirements using fossil fuels,biomass fuels and waste fuels available in industries.

THE TEMPEST

MR JOHN BOWEN, MR R W OGLESBY
EUROPEAN GAS TURBINES

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

The Tempest

JOHN BOWEN , R. W. OGLESBY.

The Tempest delivers 7.49MW(e) of electrical power to suit a wide range of utility and industrial power generation applications, including platforms and petrochemical facilities as well as paper mills, hospitals, chemical plants and other cogeneration applications.

Substantially similar to the Typhoon but scaled to achieve a higher power output, the Tempest complements EGT's existing family of industrial gas turbines comprising the Typhoon and the Tornado, both of which are available in single or twin- shaft configuration.

These gas turbines have set standards throughout the industry for efficiency, reliability and availability. Building on their heritage and demonstrated reliability, the Tempest incorporates technological advances in materials development and in manufacturing processes to deliver increased power and efficiency.

Representing design, engineering and manufacturing expertise in a compact, easy to install package, the Tempest's key features include:

- 33% simple-cycle efficiency
- excellent steam raising capability
- emissions control by dry or wet techniques
- power enhancement by steam injection
- dual-fuel and bi-fuel capability
- cold-end drive
- high availability
- on-site maintainability
- compact package arrangement
- self-diagnostic microprocessor based controls.

Compressor rotor

The 10-stage compressor is a scaled version of the highly efficient Typhoon single-shaft machine and has a 14.0:1 compression ratio and a rotational speed of 13,907 rpm. The compressor incorporates variable inlet guide vanes and the first three rows of stator blades for surge control during start up.

The compressor turbine is a two-stage overhung design comprising high and low pressure stages. Both turbine stages feature stators of advanced dihedral design resulting in optimised stage efficiency.

The high pressure turbine blades are investment cast and incorporate a corrosion and oxidation resistant coating. The blades incorporate dual, triple-pass cooling technology, providing thorough and efficient blade cooling. The first and second stage discs are cooled by air bled from the compressor, however the low pressure second stage blading requires no cooling.

Combustion

The combustion system incorporates six reverse-flow tubular combustion chambers positioned around the high pressure compressor casing.

The Tempest is offered with a combustion system suitable for operating on natural gas or distillate fuel and is available with automatic changeover from primary to secondary fuel at any load.

Reduced exhaust emissions are achieved by using a Dry Low Emissions (DLE) combustion system. Alternatively, conventional combustors, configured for steam or water injection, are available for NOx reduction or power enhancement.

A variable bi-fuel option allows the Tempest to run on two fuels simultaneously.

Bearings

The compressor spool is supported and positioned by tilting pad journal and thrust bearings which offer exceptional stability and long operating life.

Gearbox

An epicyclic type gearbox bolts directly onto the underbase and forms an integral interface and support to the engine core. Servicing is easily achieved by removal of the top half of the gearbox casing. Output speeds of 1500 rpm and 1800 rpm are available to suit 50 and 60 Hz operation.

Lubrication

The standard lubricating oil system is designed to supply oil to the engine, gearbox and generator. Filtered mineral oil is supplied from the reservoir, which forms an integral part of the underbase, by a gearbox driven main oil pump. The oil is cooled by either a water cooled oil cooler mounted on the package or an air blast oil cooler mounted off the package. Oil temperature is controlled by means of a thermostatic valve.

An A.C. motor driven pump provides pre-start and post-shutdown lubrication. In the event of A.C. failure a D.C. motor driven emergency pump supplies oil to the hot bearing and provides safe shutdown.

Starting

The standard starting system uses an A.C. motor driven hydraulic pump that provides high pressure oil to the hydraulic start motor. This rotates the turbine via a self-synchronising clutch which is mounted on the main gearbox.

Compressor cleaning

To minimise performance degradation due to compressor fouling the Tempest incorporates a compressor "hot wash" cleaning system which can be used when the engine is running on load. A cold crank wash facility is available when the engine is shut down.

Controls

A fully integrated controls package, designed and manufactured by the EGT Controls Centre, provides automatic starting running and stopping facilities, speed control, temperature monitoring, fault monitoring and annunciation. Operator information and fault indication are displayed on a high resolution colour screen. Access

to operator information is by way of front panel push buttons or a keyboard and trackerball. The display system features an on-line 500 message sequence of events recorder and an on-line trending facility for analogue and digital values, with short term trending of all mimic variables. The system can be expanded to include control of associated equipment.

Package

The Tempest is available as a packaged power plant for utility and industrial power generation applications.

The driver package incorporates the gas turbine, gearbox and all systems mounted on a single underbase. For cogeneration applications the generator is mounted on a separate underbase. Oil and gas applications will have a single-piece underbase with either multi-point or three-point mounting for onshore or offshore use as required.

The lubricating oil reservoir is located beneath the gearbox at the drive end of the package. The lubricating and start system components are mounted on the tank top and are easily accessible using the maintenance lifting frame provided.

The gas fuel system and liquid fuel valve are mounted within the underbase beneath the engine. The liquid fuel pump and filters are mounted on the lubricating oil tank top ensuring easy access for maintenance.

Intake and exhaust silencing equipment and associated ducting is designed to suit all configurations and is available in carbon steel for onshore/ inland sites or stainless steel for offshore/ coastal environments.

For noise reduction a painted carbon steel acoustic enclosure is available which is mounted on the underbase. This encloses the engine, gearbox and fluids systems and reduces noise levels to 85 dB(A) at 1 metre from the enclosure and 1.2 metres above ground level, under free field conditions.

The enclosure incorporates suitable doors and hinged lift-off panels which provide access for servicing. For offshore or coastal installations, a stainless steel enclosure is available as an option.

Weight and Dimensions:
The schematic diagrams, weights and dimension are for typical standard equipment.

Weight
Generator set : 55,000 kg (121,253 lb)

Dimensions

Overall length- driver package	**: 6.50 m (256 ins)**
Overall length--generator set	**: 9.79 m (385 ins)**
Width	**: 2.40 m (94 ins)**
Height to top of enclosure	**: 3.49 m (134 ins)**

Maintenance and Service

The Tempest incorporates a number of features that facilitate on-site maintenance and minimise operational downtime. These include:

- vertically and horizontally split intake casing which allows easy access to the air intake
- multiple borescope inspection ports which permit thorough condition monitoring without gas turbine disassembly
- horizontally split compressor casing which enables detailed inspection of the compressor rotor and stator blades
- quick change-out of the compact core which requires no alignment checks
- combustion chambers, flame tubes and ignitors which are easily accessible for inspection without removal of main engine casing.

The Tempest has planned service intervals of 8,000 fired hours, or annually, which are designed to fit in with plant maintenance schedules. A major inspection is scheduled every three years or 24,000 fired hours.

Customer Support services

EGT has a dedicated world-wide Customer Support network which comprises a range of services covering technical and practical support, training and itemised spares distribution.

-Ends-

COGENERATION UTILIZING BAGASSE AND LIGNITE AS FUEL IN INDIA

MR ANAND H. MOKASHI
THERMAX BABCOCK & WILCOX LTD.

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

COGENERATION UTILIZING BAGASSE & LIGNITE AS FUEL IN INDIA

ANAND H MOKASHI

I. PREAMBLE

In India conventionally bagasse has been used as a fuel for boilers generating steam for driving mill turbines and power house turbines. The exhaust is being used for process equipments. The trend is now to go for Co-generation wherein factories meet their own requirement and offer the electricity to the power grid. The Indian Government as well as State Government are also giving importance for co-generation

The concept of combined heat, and power generation has come of age in Indian Sugar Industry Utilisation of bagasse as a renewable, non polluting, by-product fuel is indeed ideal for such schemes. The overall potential of cogeneration placed at 10700 MW in our Country and over 3500 MW in Sugar sector appears reasonable

The experience in India though on a modest scale so far, as been encouraging and cogeneration is looked upon as an economically attractive option by the Sugar Industry.

In view of this more and more sugar factories are opting for high pressure boilers so that power can be generated with less steam consumption. Sugar factories are generally season oriented and run for 6-7 months. The balance period of the year the boilers are idle. But now with co-generation, power can be generated with other waste fuels and can be offered to the grid. Since the bagasse is not available for balance season, more and more developments are being made for alternate use of bagasse.

M/s. Thiru Arooran Sugar Factory in Tamil Nadu state have installed high pressure boiler of 66 kg/cm2 outlet with 485 Deg.C temperature i.e. first boiler in India using this high pressure technology for bagasse in sugar factory. For the balance period after the crushing season is over, M/s. Thiru Arooran would like to fire lignite to generate the power since lignite is available from nearby Neyvelli Lignite mines. Thus this is first of its own kind boiler firing bagasse as well as alternate fuel that is lignite.

II. <u>MAIN FUELS</u> BAGASSE
LIGNITE

FUEL ANALYSIS

Ultimate Analysis

%	BAGASSE	LIGNITE
H_2	3 25	1 49
C	23 50	25 78
N_2		0 30
O_2	21 75	15 58
Moisture	50 00	50 00
Ash	1 50	6 30
GCV Kcal/Kg	2272 00	2750 00
S		0 55

III. <u>UTILITIES</u>

Boiler Feed Water		Feed	Boiler
TDS (Max)	ppm	0 10	1000
Oxygen (Max)	ppm	0 007	0 007
Suspended Solids	ppm	.	
Silica (SiO_2) (Max) ppm		0.02	9
Iron (Max)	ppm	0.01	0.01
Copper (Max)		0.005	0.005
pH		8.5 9	10.8-11.2
Specif. conductivity at 25 Deg C us/cm		0 20	1111
Residual phosphates(max)ppm			30.0

Condensate		
Quality		Pure
Hardness		Nil
pH		8.5 9
Temperature	Deg.C	85

IV. BOILER DESIGN PARAMETERS

1.	CAPACITY .		
1.1	Maximum Continuous Rating	TPH	· 70
1.2	Peak rating for 1/2 hour in 8 hours	TPH	: 77
2.	PRESSURE :		
2.1	Steam pressure at main steam stop valve outlet	Kg/cm2(g)	: 66
2 2	Design Pressure	Kg/cm2(g)	: 77.5
3.	TEMPERATURE :		
3.1	Steam temp at superheater outlet at MCR	Deg.C	: 485 ± 5
3.2	Flue gas temp. leaving air preheater at MCR	Deg.C	: 160
3.3	Feed water temp. at Deaerator inlet	Deg.C	: 85
3.4	Feed water temp. at eco inlet (deaerated)	Deg.C	: 105
3.5	Steam control range	% MCR	: 60 - 100
3.6	Efficiency - on bagasse on lignite	% MCR	: 69 ± 1.5% : 75 ± 1.5%

V. FIRST OF ITS OWN KIND

M/s. Thermax Babcock & Wilcox Limited has supplied Bagasse cum Lignite fired boiler to M/s. Thiru Arorran Sugar Factory in Tamil Nadu State

This boiler has many of the first of its kind -

This is the first boiler in India of 70 ton capacity with peak of 77 ton/hr on bagasse + lignite with independent peak generation

First boiler in India for use for co-generation on bagasse + lignite

First boiler in India with 66 kg/cm2 superheater outlet pressure with steam temperature of 485 Deg C ± 5 Deg C for bagasse fired boiler in sugar factory.

First boiler in India with 8 - 10 minutes storage capacity of bagasse in the bagasse feeding chute with variable speed control on feeder

First boiler in India with panel wall construction for bagasse + lignite

First boiler in India with complete cross flow of boiler bank for bagasse and lignite

First boiler in India with electrostatic precipitation (ESP) to reduce particulated emission for Bagasse

First boiler in India with flexibility of burning various fuels other than bagasse lignite i.e. agro waste, wood chips etc.

First boiler in India for this high temperature and pressue with combination of primary and secondary SH with convection and radiation characteristics to achieve rated steam temperature in between 60% - 100% steam load range

VI. WHAT'S DIFFERENT

The cogeneration boiler unit has to essentially cater to greater expectations of the system such as -

- Higher steam pressure & temperature
- Higher steam purity
- Better combustion equipments
- Fuel flexibility
- Higher efficiency
- Better control automation
- Better system reliability, uptime and overall quality

VII. BOILER ARRANGEMENT

1. Furnace & Grate

The boiler is Bi-drum, natural circulation, radiant, top supported unit used for firing bagasse and lignite in combination or individually fired. The boiler furnace shall be membrane walled water cooled construction adequately and conservatively sized to afford adequate release rates and residence time for complete combustion of both the fuels.

Both the fuels will be fired on the travagrate. Since the capacity of the boiler is bigger, twin travagrate has been employed for the first time for firing both the fu-ls. Travagrates are driven by separate 2 hydraulic drives with separate power pack units. Since more than 160 units of this design are working all over the country, we do not forsee any problem for this type of grate for firing above fuels independently or in combination.

Since the boilers are meant for co-generation, complete furnace is used with panel walls of 2 1/2" OD tubes of carbon steel at pitch of 85 mm with finned tube so as to reduce the radiation losses and get the maximum heat extracted in furnace. The advantage of membrane wall furnace has already been elaborated separately.

Furnace has been designed to fulfil the following requirements -

A surface area sufficient to reduce the temperature of the furnace gases to a level acceptable to superheating requirements.

Sufficient height to ensure adequate water circulation in the furnace tubes

Tube dia sufficient to ensure a minimum friction drop thus to avoid an impedance to the flow of steam water mixture and to assure a flow sufficient to avoid tube overheating.

2. Superheater

The superheater shall be in 2 stages pendant type vertically suspended and combined of convection and radiation characteristics to achieve rated steam temperature in between 60% to 100% steam load range. Attemperature of interstage spray type design shall maintain the close tolerance of temperature with variation in load range.

Steam from steam drum is taken to primary SH consisting of 38 OD tubes with 4.5 mm thick with combination of carbon steel and alloy steel T11 material.

Interstage attemperator is utilised for temperature control by taking primary steam outlet to the water drum using drum coils attemperation without mixing, then, steam is taken to the secondary SH facing the furnace. Secondary SH is completely alloy steel with combination of T11 and T 22 material of 50 OD and 4.5 thick.

This arrangement gives fairly flat chacteristic with respect to the load. Sufficient mass flow has been maintained for steam so as to reduce the SH metal temperature at lower loads also.

Boilers designed for Co-generation require very high degree of superheat This calls for careful design of the superheater. The design of such superheaters requires extra care to avoid ~~steam and flue gas~~ distribution differences which could lead to tube overheating.

The mass flow selected depends on the steam pressure and temperatures as well as superheater thermal duty. In addition, the higher pressure loss associated with higher velocities improves the steam side flow distribution. In addition, superheater design must also consider following parameters -

- Requires an alloy of less cost
- Gives a more reasonable steam pressure drop without jeopardizing the tube - temperature
- Gives a high mass flow to lower tube temperature
- Gives the tube spacings that minimize ash accumulation with various types of fuel.
- Permits superheater surface to be located in a zone of higher gas temperature with a subsequent saving in surface

3. Convection Bank

The convection bank is complete cross flow. The spacing of the tubes is so arranged as to get maximum heat trasnfer with optimum draft loss and minimum erosion.

The convection bank tube consists of the boiler bank across steam drum and water drum with 50 O.D. tubes and pitch of 102 mm cross. Since the boiler has to be equipped with lignite firing which is having higher ash content, complete convection bank has been provided with complete cross flow arrangement for the first time in sugar factory in India. Generally convection bank are long flow and 2 pass, whereas here in this boilr it is single pass, cross and baffleless. Therefore the losses due to turns are also reduced and energy is saved. Also refractory baffle maintenance is eliminated

4 Economiser

Economiser of in line bare tube construction raises feed water temperature to the desired outlet temperature

Water temperature inlet to economiser will be 105 Deg.C and outlet will be around 170 Deg.C

Economiser consists of 38 OD tubes 4 mm thick with upflow arrangement and pitch is liberal (75 mm) so that erosion possibility is very low. Arrangements for provision of grit incepto is also made before eco. The grit separated can be fired back by the re-injection arrangement back to the furnace thus increasing the efficiency of the boiler

In case of economiser design, it is advisable to limit the feed water temperature leaving the economiser to well below the saturation temperature say about 25 - 30 Deg.C as this will ensure adequate circulation head. In case it becomes necessary to give steaming type economiser, the steam generated should be restricted to about 3% by wt. and separate special feed water cyclones should be given for steam separation to ensure safe circulation

5. Air heater

Tubular flue gas airheater shall be used as last stage of heat recovery to absorb the heat from flue gas to heat the combustion air to the desired degree so that the grate components shall give maximum life. Last few rows of airheater tubes are provided with corten steel in order to protect from low temperature corrosion

Air inlet temperature is 30 Deg.C and outlet temperature is 150 Deg.C . This combination would cool out the flue gases after air heater to 160 Deg.C

Air heater tubes are 63.5 OD tubes with 2.4 mm thick carbon steel. Whereas the secondary pass is made with corten steel tubes to avoid corrosion due to low metal temperature. This feature is also being made for the first time in India.

In view of very high moisture in Bagasse, attempt should be made to get as high an air temperature from air heater as possible since this will help improve bagasse combustion in the furnace. Depending upon the grate material and type of the grate the air temperature can vary anywhere from 170 Deg C to 200 Deg.C

6. Gas Cleaning

ESP has been provided with minimum draft loss and minimum particulate emission with minimum power consumed by ID fan.

After ESP has been used for the first time in India for Sugar Factory purpose.

7A. Fuel feeding

The firing system shall comprise of continuous ash discharge traveling grate, variable speed drum rotary feeders and pneumatic spreaders for firing bagasse.

Separate bagasse silo is provided for 8/10 min storage capacity so that fuel feeding is not affected even in case of some problem with mills. This is being done for the first time in India.

Two independent feeding system for bagasse as well as lignite have been made from front side. Bagasse is being fed to the boiler by means of pneumatic spreaders for which around 0.3 m3/sec. cfm air will be required at about 650mm air pressure. Hot air from the air preheater has been sucked by secondary fan and utilised for pneumatic spreader.

7B. Lignite feeding

For lignite feeding conventional drag chain carry lignite fuel from the outlet of the lignite bunker provided at the front side of the boiler. A separate emergency chute for evacuating the bunker in case of likely fire has also been provided from safety point of view.

8. Overfire air

High pressure over fire air with hot air shall be provided with 2 rows each on front side and rear wall side to create adequate turbulence to achieve high residence time to complete combustion of volatile matters in furnace. The rich mixture of flue gases thus created further travel to superheater and convection bank.

Bagasse being much Lighter fuel compared to coal or Lignite, with increased suspension burning, it becomes almost mandatory to employ overfire air system including the header nozzle openings and duct work sized for no less than 40% of the total combuston air requirement. Nozzle sizing and spacing is so decided as to get a minimum of 70% penetration.

High injection velocities are used to obtain effective burnout of the combustion gases. Spacing and quantity of air nozzles is set by free jet expansion principle. All nozzles are placed so that almost entire furnace cross section is covered while minimising jet to jet and jet to wall interface.

9. Balance draft

Boiler shall be designed to operate under balanced draft conditions and suitable dynamically balanced ID and FD fans are provided without undue vibrations.

10. Drums and Internals

The incoming feed water heated in economiser enters the steam drum and is well distributed across the length of the drum by means of perforated pipe.

The steam and water mixture collected from each wall shall be separated in the steam drum by centrifugal vortex separators. The steam is further washed by chevron scrubbers ensuring high steam purity.

Steam purity assumes increasing importance with increasing boiler pressure. Carry-over of silica and deposition on turbine blades could cause severe problems. Boiler water quality control through high quality of feed water and requisite blowdown are essential. The drum is fitted with high efficiency steam/water separators and steam purifiers. Any compromise in either the design or installtion of these drum internals can cause problems not only in turbine but the superheater tubes due to internal scales causing high metal temperatures. Many operating units are found to be plagued with choked superheater tubes due to bad water quality and erroneous drum internals.

VIII. ADVANTAGES OF TRAVAGRATE FIRING SYSTEM

Flexibility of burning various fuels like Bagasse, Lignite, Coal, Wood chips, agrowaste etc

Complete automation including automatic combustion control to regulate bagasse flow and corresponding air control.

The TRAVAGRATE boiler facilitates quick response to load change as it retains the advantages of partial burning of bagasse in suspension.

Though special grate design of the TRAVAGRATE, air leakages are prevented, which maintains low excess air and results in higher efficiency of the boiler

Continuous ash discharge eliminates pressure fluctuations

The TRAVAGRATE of TBW design is the most robust design using special shell moulded castings to ensure dimensional accuracy, maintaining close tolerances for long trouble free operation.

The proof of this is that more than 160 units with such travagrate are in operation throughout the country.

IX. ADVANTAGES OF MEMBRANE WALL FURNACE

The membrane panel has the following advantages -

1. This ensures gas tight enclosure which reduces leakage to an absolute minimum in the furnace, all guarantees and calculations will be based on less excess air. This also reduces fuel cost.

2. Reduces a fan power requirement as reduced leakage means a lower volume of gas at a lower system resistance. Gas weights handled by the inducted draft fan will be lesser and draft losses less.

3. Reduces furnace maintenance because -

a It greatly minimizes slagging and its effects. Since the membrane furnace stays free of slagging, low furnace exit gas temperatures are maintained.

b. It simplifies tube repair. Although the wide spaces tubes are relatively easy to weld in place, but on the tube and tile wall heavy outer casing and tile must be removed and replaced. With the tangent tube wall, tube replacement is diffcult since there is no clear space between tubes for access, and tubes must be cut loose from tie bars and jacked out of line before ring welding, and then jacked back into place and reconnected to the tie bars The spacing provided by the membrane wall permits in place ring welding simply by buring through the membrane, with only insulation and light gage lagging to remove.

4. Permits production from the unit sooner by reducing erection time because -

a. Maximum shop sub-assembly - Minimum number of large sections to handle reduction in number of small parts that must be field assembled.

b. No great quantities of brickwork or refractory to instal

c. Less pressure part welding at site because sidewall headers are shipped connected to the wall panels.

5. Increased resistance to damage to the unit from furnace puffs when auxiliary fuels are fired since "unibody" construction of membrane wall can handle more force without buckling or bowing than a segmentally constructed tangent tube or tube and tile wall

6. Reduces foundation requirements because membrane wall weighs less than any other construction available today.

X. FOCUS ON OVERALL QUALITY

Sooner rather than later the concept of spare boiler in Sugar factory has to go. With this a higher reliability will be demanded from the boilers. Such reliability has a better chance to come by if the boiler makers and users install the Quality Management System such as ISO-9000 and ASME - S, R, PP, U in their respective organisations. Such systems cover every aspect of boiler making from design performance. Once the operation and maintenance also come under the discipline of these Quality Management Systems and results can be extraordinary.

The sugar industry has a very high familiarity with boilers. A slight change in the mind set and management initiative can easily change the situation favourably.

XI. CONCLUSION

Co-generation in sugar plants is definitely a cost effective way of generating and exporting power

The COGEN boilers belong to almost the same class as power station boilers

The enhanced expectation of reliability can be met by carefully chosen design of various components and systems using state-of-the-art design procedures and programme.

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Boiler makers and users O&M departments should try to install systems to ISO - 9001, ASME self certification system etc., ensuring operation of thorough Quality Management Systems.

With the increasing size of sugar plants and increasing prices of fuel, an overall urge for high efficiency can be clearly seen and therefore the need for more efficient boiler distinctively superior to the older designs.

TBW with the back-up of World's Largest boiler makers i.e. Babcock & Wilcox, USA is capable of offering right technology and is in possession of the infrastructure.

To meet the demands of co-generation arrangements, a real multifuel boiler with high pressure of 66 kg/cm2 and with high temperature of 485 Deg.C. can be achieved with maximum possible efficiency with trouble free service throughout the year.

As elaborated earlier, this boiler has got many of the salient features of first of its own kind.

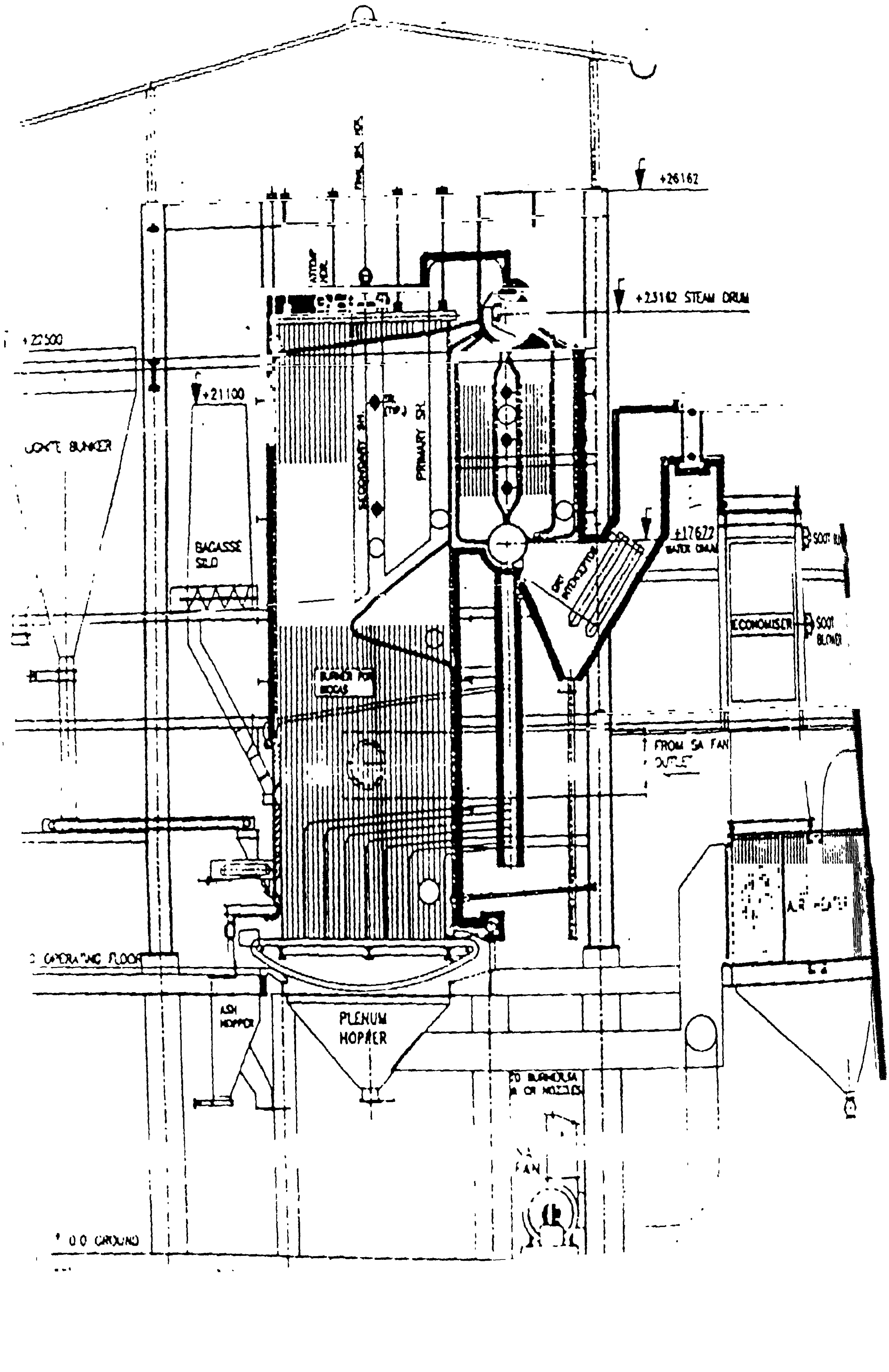
ACKNOWLEDGEMENTS

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Sincere thanks are due to the organisers of this seminar for allowing me to present this paper

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TEA INDUSTRY: TECHNOLOGICAL OPTIONS FOR COMBINED HEAT AND POWER (CHP) SYSTEMS

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Cogen INDIA '96
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Tea Industry: Technological Options for Combined Heat and Power (CHP) Systems

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Abstract

Tea industries need large quantity of thermal energy (for drying, withering, etc.) and electrical energy (for plant operation, irrigation, lighting, etc.). As tea gardens are located in remote hill areas, they have to depend upon firewood and captive diesel gensets as supply of coal and grid electric supply is not sufficient and reliable. Combined heat and power (CHP) system is an alternative to complete reliance on grid supply, besides incentive for fuel savings. The present paper describes several technological options for CHP systems. Comparative analysis of various options indicates that gasifier coupled diesel engine cogeneration system is the most suitable option for tea industry.

Introduction

India is the largest producer of tea in the world accounting for about 28% of world production with an estimated annual production of 720 million kg of tea [1]. In processing of tea, energy is used at various unit stages. Two processing methods, "CTC" (cut-tear-curl) and "Orthodox" (classical), have generally been adopted by tea manufacturers. Around 56% of manufacturers use CTC and the remainder use orthodox method.

The production of tea from green leaves is essentially a gradual oxidation process. Green leaves after harvest go through the following stages:

(i) Withering
(ii) Rolling and cutting
(iii) Fermentation
(iv) Drying
(v) Grading and packing

Energy use scenario in tea industry

In initial stages of the industry, only wood was utilized for thermal applications as thick natural forests were existing around plantation areas. As time passed, forest cover gradually decreased and industry started utilizing other fossil fuels. For the year 1989, the total fuel consumption for drying 720 million kg of tea was as follows [2]:

Coal	=	0.50 million tons
Fuel wood	=	0.25 million tons
T.D. oil	=	40,000 kilo litres
Furnace oil	=	20,000 kilo litres
Diesel	=	25,000 kilo litres
Leco	=	15,000 tons
Natural gas	=	5 million Nm^3

For operating machineries used for tea processing, lighting, irrigation pumping, etc. tea industry consumes more than 500 million units of electricity per year. Since grid electric supply is not reliable, all tea estates have captive diesel gensets consuming about 80,000 kilo litres of diesel annually. Total installed capacity of gensets in Indian tea industry is about 2000 MW.

The major fraction of energy consumed in tea processing is spent in the drying process consisting of an air heater, a feeding system for tea, dryer, blowers with associated ducting and cyclone separators for removing tea dust in the hot flues. Old factories use continuous tray dryers, but these are being replaced by fluidised bed dryers in modern large scale tea factories. Thermal analysis of these systems shows that, though the performance of the dryer system has considerably improved due to technological innovations, there has not been a significant improvement in the efficiency of air heater [3]. The thermal and electrical consumption figures for present tea drying process are shown in Table 1 [4].

Table 1: Average thermal and electrical energy consumption at various stages in tea processing

Processing stage	Energy consumption			
	CTC		Orthodox	
	Thermal (kWh/kg)	Electric (kWh/kg)	Thermal (kWh/kg)	Electric (kWh/kg)
Withering	0.70	0.11	1.08	0.14
Drying	3.80	0.04	3.30	0.04
Others[1]	–	0.45	–	0.40
Total	4.50[2]	0.60[3]	4.38	0.58

1. Rolling, fermentation, grading and packing
2. Range evaluated: 3.78 – 5.22
3. Range evaluated: 0.55 – 0.65

It is apparent from Table 1 that drying consumes the highest fraction of energy. As mentioned earlier, coal is the main source of energy in the north-eastern estates while fuel wood is predominantly used in southern estates. With increased availability of oil and natural gas, the northern estates are utilizing more and more of oil and gas, but the southern estates

are still using firewood grown on captive forests. A more serious problem faced by the tea industry is frequent power cuts, which is a regular phenomenon in hill areas where tea gardens are generally located, making the grid electric supply unreliable. Hence the use of diesel genset has become a necessary practice in tea industry.

From the above discussion, it is apparent that a combined heat and power (CHP) system would be highly desirable for the tea industry. Some technological options of CHP systems are described in the following sections.

Some technological options for CHP systems

Industrial use of combined heat and power (CHP) systems or cogeneration systems leads to small, dispersed electric power generation installations — an alternative to complete reliance on grid power supply. Fuel saving is the major incentive for the use of CHP systems. Since all the heat engine based electric power systems reject heat to the environment, this rejected heat can be used to meet all or part of on-site local thermal energy needs. Use of rejected heat usually has no effect on the amount of primary fuel used, yet it leads to a saving of the fuel that could otherwise be used for the thermal energy process. Heat engines also require a high temperature thermal input and in some situations can obtain the input thermal energy as the rejected heat from a higher temperature thermal energy process. In the former case, the cogeneration process employs a heat engine topping cycle; in the later case, a bottoming cycle is used. CHP systems can be designed from two perspectives: they can be sized to meet the process heat needs and electricity produced is treated as a by-product, or they can be sized to meet electrical power demand and the rejected heat is then used to supply process heat needs.

Most common heat engine systems for CHP systems are:

- Steam turbines (back pressure and extraction type configurations)
- Combustion gas turbines (open or closed cycle type)
- Diesel engines

Each heat engine type has unique characteristics making it better suited for CHP applications than others. For example, engine types can be characterized by:

- Power to heat ratio at design point.
- Capacity range
- Power to heat ratio variability
- Part load (off-design) efficiency
- Multi-fuel capability

The major heat engine types are described in terms of these characteristics in Table 2 [5]. Representative CHP systems for each heat engine type are described in the following sections.

Table 2: Cogeneration characteristics for heat engines

Engine type	Steam turbine		Combustion gas turbine	Diesel Engine
	Extraction condensing type	Back pressure type		
Efficiency at design point	0.25–0.30	0.20–0.25	0.25–0.30	0.35–0.40
Part load efficiency	Fair	Fair	Poor	Good
Multifuel capability	Excellent	Excellent	Poor	Fair to Poor
Maximum temperature of recoverable heat (°C)	93–315	93–315	538–649	260–371
Recoverable heat (kcal/kWh)	280–8800	4300–17600	800–2800	100–1600
Typical power to heat ratio	0.10–0.30	0.05–0.20	0.30–0.45	0.60–0.85

Steam turbine systems

Both back pressure and extraction condensing steam turbine systems can be used. The back pressure configuration is better suited for applications in which power to heat ratio is low and relatively fixed. Extraction condensing steam turbines offer greater variability of power to heat ratio (through changes in the amount of extracted steam) and a higher power to heat ratio (when extracted steam is minimized). The extraction condensing cycle must always condense the steam flow which passes through the full pressure ratio of the turbine; the extracted steam may or may not need to pass through the condenser, depending on the temperature limits of the heat and whether or not it condenses the steam flow. For the back pressure configuration, the need for a condenser depends on whether the heat load itself condenses the steam flow or not.

Combustion gas turbine systems

Gas turbine operates on the Brayton cycle. In a combustion turbine a clean fuel is burned directly in the compressed air working fluid and the combustion products are then expanded through the turbine and exhausted to the atmosphere. The combustion gas turbine system provides a higher power to heat ratio than typical steam turbine configuration (See Table 2). Of all the systems considered the combustion gas turbines also provides heat at the higher temperature (upto 650°C). The major draw back of combustion gas turbine system is their

poor part load efficiency and the requirement for clean fuel to avoid erosive or corrosive damage to turbine.

Diesel engines

Diesel engines have been used in small scale cogeneration applications. They are characterized by high engine efficiency (See Table 2), good part load characteristics, a relatively low rejected heat temperature and a high power to heat ratio. Diesel engines supply process heat in two forms: low temperature (93 to 121°C) engine coolant, and higher temperature (260 to 370°C) exhaust gas.

CHP system for tea industry

A typical tea garden producing 4 lacs kg of tea annually is considered to calculate power to heat ratio in order to decide which CHP system is suitable. It is assumed that a dryer having capacity of 300 kg/hr of made tea is installed in this tea factory. The amount of hot air needed for tea drying at 120°C for Pandian plug flow tea dryer (the value is taken from their product catalog) is:

$$= 9.5 \times 10^3 \ Nm^3/hr$$
$$= 11.4 \times 10^3 \ kg/hr$$

Amount of heat required to heat air from 20°C to 120°C will be:

= 273600 kcal/hr
= 318 kW (thermal)

Electrical power required for rolling, fermentation, grading and packing, etc. will be:

$$= 0.6 \times 300$$
= 180 kW

For a typical tea garden, amount of electricity required for lighting (factory and residential campus within tea garden), irrigation pumping, flour mills, etc. is about 50 kW.

Thus the total electrical power needs of a tea garden having one tea dryer of 300 kg/hr capacity will be 230 kW.

Hence the power to heat ratio is 230/318 or 0.72.

Referring to Table 2, it can be seen that the diesel engine cogeneration system is the most suitable option for tea industry. The schematic diagram of diesel engine cogeneration cycle is shown in Figure 1.

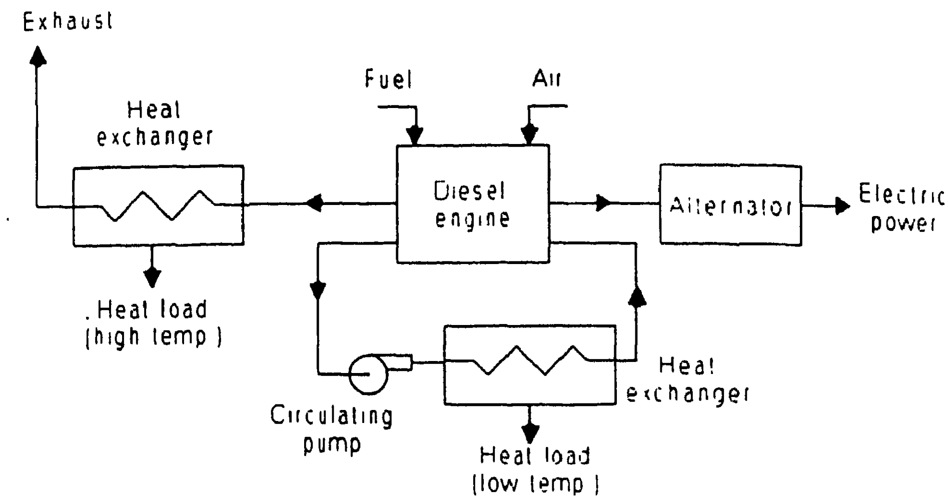


Figure 1: Diesel engine cogeneration cycle

Potential of wood gasifier systems

Tea estates at present depend on firewood which is grown on captive forests due to insufficient and unreliable supply of coal and leco. Captive diesel genset are used to meet roughly 40% of electricity demand consuming large quantities of diesel every year, prices of which are rising sharply and steadily due to its acute shortage in the hilly regions of south India. Wood gasifier systems can be used to obtain producer gas which can be used to run diesel genset of the CHP system on dual fuel mode in order to replace 65–75% diesel consumed resulting in large saving of diesel oil. This will make diesel genset CHP system more attractive due to reduction in cost and due to the fact that existing diesel gensets can be used for this purpose, needing less additional capital investment. Figure 2 shows detailed flow chart of diesel engine CHP system for tea industry utilizing wood gasifiers.

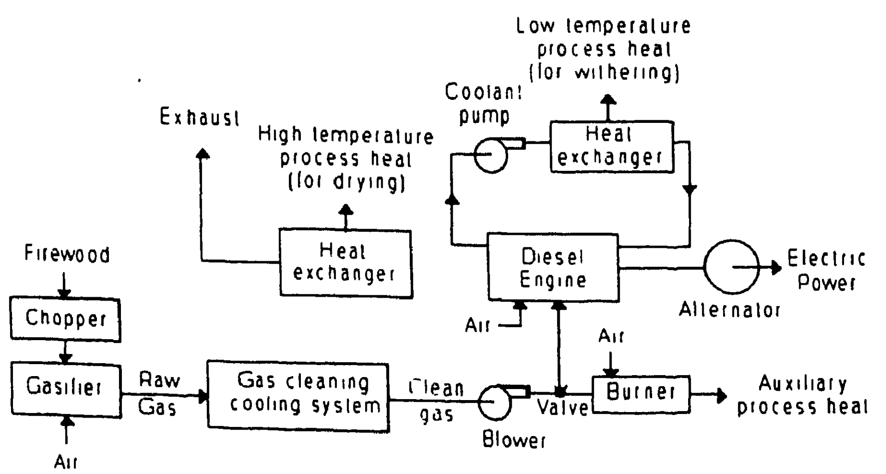


Figure 2 Wood gasifier based diesel engine cogeneration system for tea industry

Conclusions

Tea processing is an energy intensive process requiring large quantities of thermal energy for drying and electrical energy for operating machineries, lighting, irrigation pumping, etc.. Out of several CHP options available, diesel engine cogeneration system is found to be most suitable, for meeting processes heat and power requirement of tea industry. Induction of wood gasifier system in diesel engine CHP system makes such a system highly economical and desirable.

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CO-GENERATION POWER PLANT SET UP FOR THE CHEMICAL COMPLEX AT MITHAPUR

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Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

Presentation at the Cogen INDIA 96
February 18-20, 1996

By

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President-Chemicals Division,
Tata Chemicals Ltd., Mithapur.

Co-generation Power Plant set up for the Chemical Complex at Mithapur.

Tata Chemicals Ltd. since its inception in 1939 passed through innumerous trials and tribulations, surmounted many hurdles through shear dedication and perseverence of its employees alongwith its inspired leaders to emerge as a single largest Soda Ash producer in the world by synthetic route. Now it is the largest Inorganic Chemical Complex not only in the country but in this part of the world. This was possible only because of the long term goals of the House of Tatas towards the industrial development of the country particularly in the basic industry that they absorbed the losses the company suffered during the initial 18 years and did not give up. Then under the dynamic and inspiring leadership of our Chairman Emeritus Mr Darbari S Seth, the Company turned the corner and we never looked back. The present position that the Company holds is the result of his able stewardship for all these years.

The concept of co-generation of steam and power for the Chemical Complex was adopted since the inception of Tata Chemicals as at that time in 1939 there was no infrastructure available in this remote part of India. There was no power, not even roads worth the name. There was only one metre gauge rail line going upto Port Okha. So Tata Chemicals had to build everything for their requirement and their survival.

For any chemical process either there is an exothermic reaction where heat is generated or there is an endothermic reaction where heat is consumed. In order to provide for such heat transfer, the best medium selected is steam. Based on this principle, we sized our steam and power plant in a manner that we generate steam at a higher pressure, in our case at 110 kg/cm2, and 515° C, generate power through the high pressure turbines, which we call as Topping Turbo-generators and exhaust steam from these turbines at 30 kg/cm2. Part of the steam at 30 kg/cm2 is used in driving CO_2 Compressors, boiler feed pumps and also used in steam heated calciners. The balance steam passes through low pressure turbines with extraction facilities to draw steam at 10 kg/cm2 pressure, 3.5 kg/cm2 and the balance at the back pressure of 1 kg/cm2. All these streams of low pressure steam are used in various plants for heating purposes.

We do not work any condensing turbine where the latent heat of the lowest pressure steam would be lost into the sink. We have adopted this total energy concept in our co-generation steam and power plant which gives us an overall thermal efficiency as high as 70%. During any unbalanced conditions of plant operations when the steam and power demands do not match, we have provided pressure reducing and desuperheating stations to meet the demand at required pressure and temperature conditions. Our turbine governing system is also provided for both speed and back pressure controls which can be switched over from one to the other. In addition, we now have a tie up with Gujarat Electricity Board to supply or draw power to or from the grid as per our plant conditions. This tie up was started with the intention of supplying our surplus power to GEB, but once in a while due to upset plant conditions, we do draw some power for short durations.

Our present installed capacity of steam and power is 550 tonnes per hour of steam and 55 MW of power.

In 1992 we took up the installation of Cement Plant at Mithapur, started the expansion of Soda Ash from 700,000 TPY to 1 million TPY and also added new Caustic Soda Plant of 100 TPD based on the Membrane Cell technology. All this required additional power and steam, so we decided to go for a new boiler and TG set. We selected this boiler on the latest Circo Fluid Bed Combustion technology and ordered the boiler on M/s Krupp Industrties India Ltd., Pune, who had the technical collaboration with Lurgi Lentjes Babcock Energietechhnik GMBH Germany. It has steam generation capacity of 200 TPH at 112 kg/cm2 pressure and 565° C temperature. We were the first in India to place an order for this type of boiler of this large capacity and temperature rating. The salient features of this boiler are, that it is a tall tower type boiler with membrane walls, minimum flue gas velocities of 3-5 m/sec required for fluidisation, maintaining combustion temperature in the bed upto a maximum of 950°C, capable of burning either coal or lignite without any adverse effects of slagging. The generating tubes, superheaters and one economiser are suspended inside the furnace which absorb maximum amount of heat before the flue gases go to the cyclones, where the maximum temperature is 450°C. In FBC boiler terms these are called cold cyclones. In order to capture sulphur in lignite this boiler is provided with limestone feeding system which reacts in the bed at temperatures below 950°C to form $CaSO_4$ and the stack emission for SO_2 can be controlled to 100 PPM. As the furnace temperature does not exceed 950°C the formation of NOX automatically remains within 100 PPM meeting the latest pollution control norms. Particulate emission is controlled to less than 150 mg/NM3 by a large ESP. We have a continuous stack monitoring system for particulate emission, SOX and NOX.

M/s BHEL were given the order for turbo-generator set for steam inlet conditions of 110 bar and 565°C. The turbine was rated to generate 16.5 MW power with a back pressure of 30 kg/cm2. In order to design the turbine for 565°C temperature rating, M/s BHEL had to take the help of Siemens, Germany as all the utility power plants in India have the maximum temperature rating of 545°C.

Our Circo Fluid Bed Boiler was first commissioned in January 1995. After initial teething troubles we were able to run the boiler for a few weeks, when we decided to shut down the boiler and carry out the inspection inside to make sure that everything was fine. But to our utter surprise, we found that the refractory lining in the furnace portion as well as in cyclones had totally peeled off. On investigation, it was found that the refractory material supplied was of poor quality. We consulted ACC experts and selected an alternative material which was supplied and its application was supervised by ACC. It took us two months to re-start the boiler.

Thereafter we had a few tube leakages in the economiser section, superheater and water wall areas due to poor quality of materials and poor workmanship, which were attended as and when the leakages occured. During these incidents once the bed got flooded and second time the water from economiser tube leakage got carried over to the first ESP hoppers, which required thorough cleaning.

Subsequently we encountered a few tube leakages in superheater and economiser sections which are suspended inside the furnace and those leakages were due to heavy erosion on the outer surface of the tubes. This was attributed to certain misalignment of the coils and inappropriate shielding of the tubes from the impact of ash in circulation. Representatives from M/s KIIL, Pune and M/s LLB, Germany were called to sort out these problems. The rectifications as suggested by them were carried out and now the boiler is running smoothly.

It is nearly one year now since the boiler was first started and average availability so far has been 60%. We did achieve full rating of the boiler and the performance tests both on lignite and coal as fuels were carried out. The thermal efficiency calculated was over 88% for coal and over 87% for lignite which exceeded the guaranteed figures.

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CO-GENERATION AT J.K. PAPER MILLS

MR. B T SRIDHARAN
J K CORP LIMITED

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CO-GENERATION AT J.K. PAPER MILLS

Indian Industry is today facing an acute power shortage in the country. In some states, Industries are being subjected to power restrictions to the tune of 50 to 70%. Even in the states where power position is comfortable, the peak load restrictions are imposed and for continuous process industry there is always a danger of overload tripping / low voltage. The co-generation potential available in the country is around 15,000 MW in the industries sector. If the power is tapped, then it will not only ensure economical, attractive power option but could also contribute to a betterment of the environment which is a very important factor now-a-days.

The industrial sector today in India account for about 45% of the total consumption of electrical energy. There are industries where both steam and electricity are required for use. These industries such as fertilisers, textiles, petro-chemicals, paper, cement and ceramics can opt for co-generation.

Co-generation offers the following benefits to industry:

- ❑ To generate total internal energy requirement and non-dependence of external agencies
- ❑ Surplus energy generated can be supplied to the State Electricity Boards at competitive prices.
- ❑ It reduces the overall green house, gas emissions and hence reduces air-pollution.

In any process industry, steam is widely used for heating/drying either directly or indirectly and also to run the prime-movers with varying pressures and temperatures. Steam is usually generated at higher pressure and temperatures than required for process. To bring higher pressure steam to required level, steam is expanded in a steam turbine and extracted at required pressure and temperature.

The steam turbine is coupled with generator to produce power for internal consumption of the industry. This type of power generation as well as steam for process use is called as "Co-generation".

Co-generation is widely used in Pulp and Paper, sugar, fertiliser, textile, rayon fibre and petro-chemical industries. In Paper Industry, steam is mainly used for cooking of chips in digesters to make pulp and drying of paper in paper machines at different pressures and temperatures besides usage in evaporators of Black Liquor.

In JK Paper Mills, with an installed capacity of 75,500 TPA paper production, co-generation is extensively used for process. Saturated steam at 10 kg/cm ^{2} (g), 200°C is required for Digesters and bleaching plant for pulping and at recovery boilers for air-heating. Steam at 2.8 kg/cm ^{2} (g), 150°C is required for Paper Machines, coating plant, laminating machines, pulp drying plant for drying purposes, at evaporators for increasing the concentration of weak black liquor and also at de-aerators, causticizing plant and chlorine dioxide generating plant.

PRESENT STATUS OF CO-GENERATION AT JK PAPER MILLS

Presently, steam is generated from various capacity coal fired boilers as per Annexure-I at 36 kg/cm² (g), 400 C with cumulative steam maximum generation capacity of around 112 TPH. The Boilers are generally operating at a thermal efficiency of around 78 to 80%.

All the four Coal Fired Boilers are of bi-drum, water tube, natural circulation type with integral furnace design and they are provided with superheaters with spray type attemperator and economiser. Two deaerator feed tanks each of 2.3 m diameter 5.5 m length, with storage capacity of around 19 m³ are provided which can cater to all the four boilers' generation under MCR conditions for 16 minutes. All the four boilers have common feed water system with two deaerators and five feed pumps. The delivery headers of the feed pumps of both feed tanks are inter-connected. Normally, deaerator capacity should cater to 20 minutes of boiler capacity at MCR conditions.

These boilers adopt balanced draught system with dedicated forced and induced draught fans. These boilers are provided with separate mild steel bunkers for storage of coal.

All coal fired boilers are provided with furnace draught control, drum level control and superheated steam temperature control.

Coal fired boilers No.1 and 2 are provided with dedicated electrostatic precipitators supplied by Bharat Heavy Electricals Limited and connected to a

common steel chimney of height 40 m to which Liquor fired boiler No.3 is also connected.

Coal fired boiler No.3 is provided with dust cyclones and is connected to a RCC Chimney of 40 m height. Coal fired boiler No.4 is also provided with dust cyclones. Coal fired boiler No.4 and Liquor fired boiler No.4 are connected to a common RCC chimney of 53 m height.

JK Paper Mills had experienced lower output from Coal fired boilers No.1 and 2 due to persistent grate problem and poor quality of coal. The thermal efficiency of the boilers was also low. Hence, JK Paper Mills modified these boilers to change the chain grate stoker combustion system to fluidised bed combustion system. Accordingly, in 1994, both the boilers were converted to FBC system and are in operation.

The modification to FBC conversion involved the following :

a) Removal of existing grade, ID Fan, FD Fan, Secondary fans.
b) Addition of extra heating surface in bed coils.
c) Modification of furnace tubes for boiler start-up purpose.
d) Addition of LDO oil firing system for better start-up purpose.
e) Addition of flue gas system, air preheaters with suitable ID and FD Fans relocated as per requirement.
f) Installation of individual electrostatic precipitators.
g) Installation of dense phase fly ash collection system with a common steel silo.
h) Installation of new coal handling plant.
i) Modernisation of instrumentation.

The above modifications have improved performance of the boilers. The details of the coal fired boilers are given in Annexure-I.

There is a chemical recovery boiler (Liquor Fired Boiler No.4) of 300 TPD dry black liquor solids firing capacity from which steam is generated at 37 kg/cm^2 (g), 400°C.

LIQUOR FIRED BOILER (LFB-4):

This Liquor Fired Boiler, supplied by BHEL and commissioned during 1988, is designed to handle 300 TPD of dry black liquor solids. This us a COMBUSTION ENGINEERING design boiler, employing suspension drying of black liquor.

The boiler is of top mounted, natural circulation, bi-drum, fusion welded membrane panel type construction with screen tubes, two stage superheaters and boiler bank. A spray type desuperheater is located between the primary and secondary stage superheaters.

This is provided with a twin cascade evaporator for secondary evaporation of black liquor from the evaporator plant.

A twin chamber electrostatic precipitator is installed for recovery of chemicals from flue gas.

BASIC DESIGN PARAMETRS OF LFB-4

Sl. No.	Description	Unit	
1	Furnace dimensions - Area - Depth - Width	 m^2 mm mm	 17 4292 3937
2	Firing Capacity (BL Solids)	TPD	300
3	Calorific value of BL (on dry basis)	K.Cal/Kg	3,100
4	Concentration of BL to cascade evaporator	%	50
5	Superheated steam flow	kg/h	27,000
6	Superheated steam pressure	$kg/cm^2(g)$	37
7	Steam temperature	°C	410+/-8
8	Feed Water temperature	°C	102
9	Water for desuperheater	kg/h	1,310

The requirement of power at JK Paper Mills is met by captive power generation (co-generation) from 2.5 MW, 5.4 MW and 12 MW Turbo sets and drawing balance power from Orissa State Electricity Board. The average peak power requirement at present production level is about 14.3 MW. After installation of 12 MW TG Set and considering the shutting of 2.5 MW TG Set, the generation is about 9 MW which is about 60 % of the power demand and also meets process steam requirements. After commissioning of new coal fired boiler 5, the generation is expected to be about 14.5 MW. This co-generation will meet complete power requirement of the plant with the excess steam being condensed at present production level and also dependence on State Electricity Board will cease to exist.

The 2.5 MW set is a double extraction and condensing set supplied by SIEMENS designed for inlet steam pressure of 37 ata at 400°C, externally controlled medium pressure steam extraction at 26 ata and internally controlled

low pressure steam extraction at 3.8 ata. Presently, MP extraction is dummied. The maximum LP extraction and condensing potential from this set is 19 tph and 7.2 tph respectively. The speed of the turbine is 8000 RPM and that of the alternator is 1500 rpm.

The 5.4 MW set is a double extraction and condensing set supplied by BLOHM+VOSS and designed for inlet steam pressure of 36.3 bar at 400°C with internally controlled medium pressure steam extraction of 11.3 ata and internally controlled low pressure steam extraction at 3.7 ata. The maximum capacity of MP, LP extraction and condensing possible is 20 tph, 30 tph and 17.5 tph respectively.

The 12 MW TG set is a double extraction-cum-condensing TG set manufactured by Gorlitz, Germany, designed for inlet conditions of 44 kg/cm^2(g), 450°C. However, the turbine has been modified to suit steam parameters of 36 kg/cm^2(g), 400°C. The speed of the Turbine and the alternator is 3000 rpm.

The total steam and power balance are as per Annexure-II.

PROPOSED EXPANSION:

After the Mill expansion, when the total paper production will rise to 1,60,000 TPA, the steam and power requirement will raise 170 TPH and 30 MW respectively. To achieve this increased steam and power requirement for the Mills, plans are afoot to go in for further co-generation so that the cost of power required for the mill is much below that of purchased power from OSEB,

besides dependence on OSEB is reduced. Also co-generation will help in substantial saving in energy which is very vital now-a-days.

To meet the entire power requirement of the 30 MW of the Mills, the anticipated power generation through process steam (co-generated power) is around 15 MW which is about 50 % of the total power demand.

In order to meet balance power requirement of 15 MW, around 56 TPH is to be condensed utilising condensing facility available with all turbo-alternators including new turbo-alternator for generating about 10 MW from the new Turbo-Alternator and balance 5 MW from the State Grid.

Based on above computation, the steam generation requirement from the proposed coal fired boilers is arrived at 121 TPH after accounting for steam generation from existing coal fired and liquor fired boilers and proposed two recovery boilers (LF Boiler V and VI). Accordingly, the cumulative installed capacity of coal fired boilers of 150 TPH is selected to build-up necessary margins required to meet the process packing, fluctuation in the steam generation of the chemical recovery boiler and for control purposes.

To meet 121 TPH steam, we have already ordered a new 60 TPH boiler which is scheduled to be commissioned by August, 1996. It is proposed to have a new 90 TPH (Coal Fired Boiler VI) MCR Boiler to meet the balance steam requirement considering the requirement of 2 boilers (CF Boiler I and II). One Boiler of 30 TPH will be kept as a standby to take care of any breakdown and annual inspections of any boilers. In the proposed expansion the details of coal fired boiler are given in Annexure-III.

During annual inspection of new boilers (CF Boiler V and VI) to meet the power demand, the mill may have to draw more power from OSEB.

The total power requirement after the expansion of the Mills is around 30 MW and is proposed to be met by generating :

- ❑ 4.6 MW from existing 5.4 MW TG Set
- ❑ 10.2 MW from existing 12 MW TG Set
- ❑ 10.2 MW from proposed new 12 MW TG Set

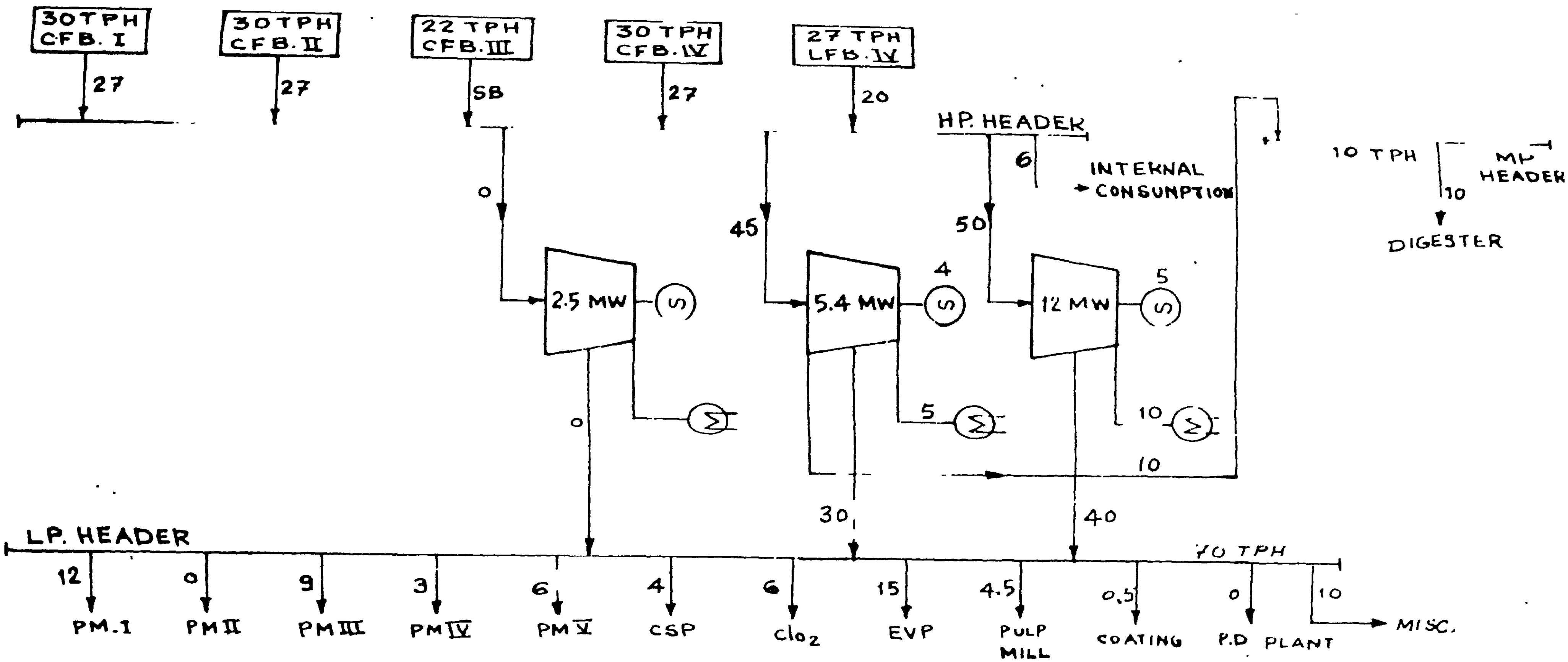
The anticipated steam and power balance of the Mills after expansion, is as per Annexure-IV.

Encl: **Annexures-I, II, III & IV.**

Annexure-I

DETAILS OF THE COAL FIRED BOILERS (Existing)

Sl. No.	Description	Unit	CF Boiler-I	CF Boiler-II	CF Boiler-III	CF Boiler-IV
1	Make		Steinmuller	Steinmuller	Walchandnagar Industries Ltd	Walchandnagar Industries Ltd
2	Type of combustion		FBC Boiler (Converted in 1994)	FBC Boiler (Converted in 1994)	Travelling grate spreader stoker	Travelling grate spreader stoker
3	Year of installation		1962	1962	1981	1986
4	Working Pressure	ata	36	36	36	37
5	Working Temperature	oC	410	410	410	410
6	Maximum Continuous Ratin (MCR)	TPH	30	30	22	30
7	Feed Water Temperature to Economiser	oC	102	102	102	102
8	GCG of design fuel (coal)	K.Cal./k	3500	3600	5251	4000



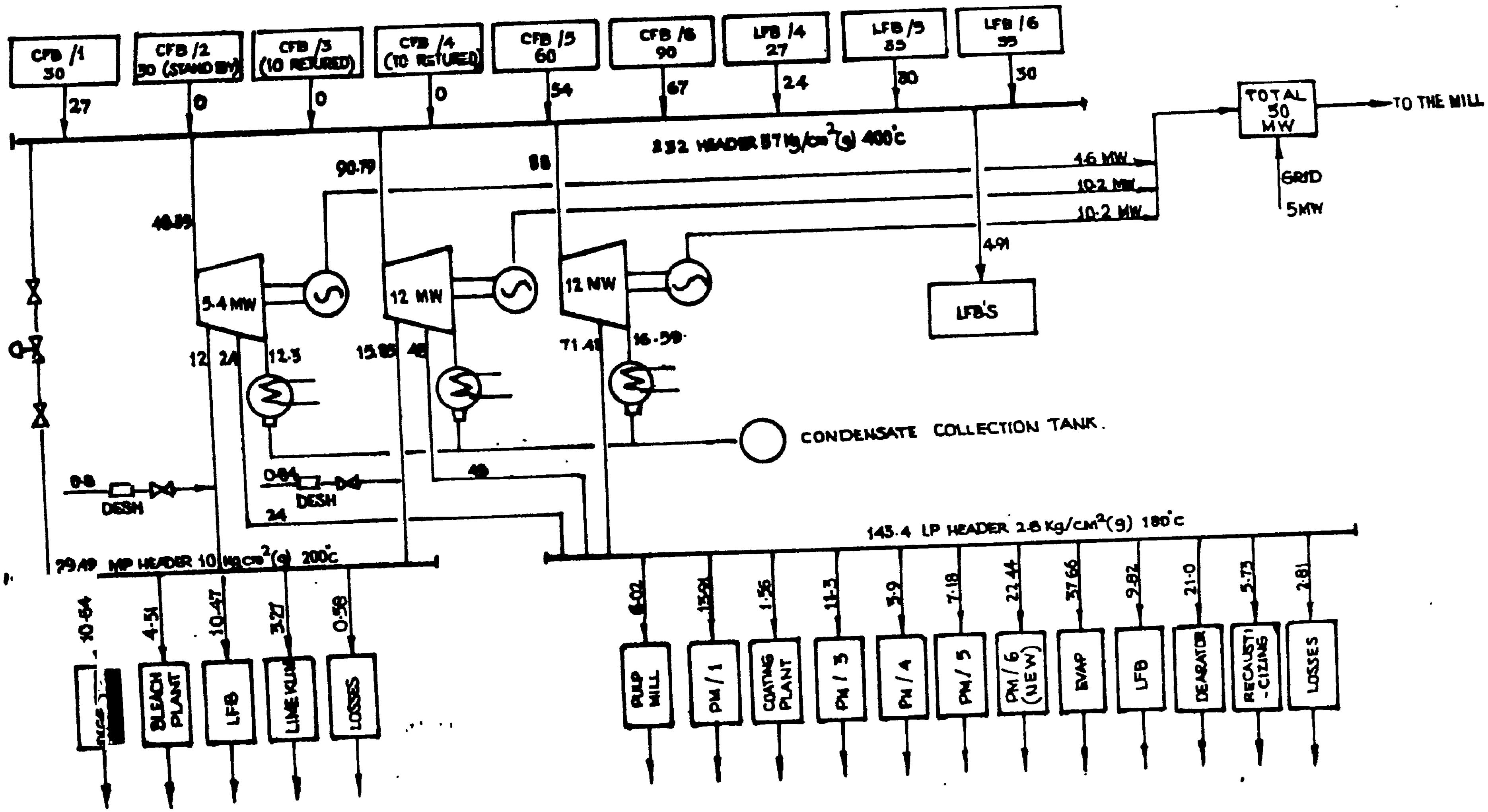
STEAM & POWER BALANCE
(75500 TPA PRODUCTION)

ANNEXURE - II

Annexure-III

DETAILS OF THE COAL FIRED BOILERS (Proposed)

Sl. No.	Description	Unit	CF Boiler-I	CF Boiler-II	CF Boiler-V	CF Boiler-VI (Proposed)
1	Make		Steinmuller	Steinmuller	T B W	
2	Type of combustion		FBC Boiler (Converted in 1994)	FBC Boiler (Converted in 1994)	F B C	F B C
3	Year of installation		1962	1962	1996	1998
4	Working Pressure	ata	36	36	37	37
5	Working Temperature	oC	410	410	410	410
6	Maximum Continuous Rating (MCR)	TPH	30	30	60	90
7	Feed Water Temperature to Economiser	oC	102	102	102	102
8	GCG of design fuel (coal)	K.Cal./k	3500	3600	3500	3500



PROPOSED STEAM AND POWER BALANCE

ANNEXURE - IV

WASTE HEAT RECOVERY FROM FLUE GASES WITH SUBSTANTIAL DUST LOAD

DR. J M CHAWLA
CALDYN INC., USA

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

Waste Heat Recovery from Flue Gases with Substantial Dust Load

J.M. Chawla[1]

Introduction

A lot of energy is wasted with the flue gases (Fig. 1) in cement plants, steel and non-ferros metallurgical plants, electric arc furnaces, refractories and other associated industries. Most of the flue gases with temperatures between 250° C and 450° C contain substantial amounts of dust and have to be quenched in a gas conditioning tower by complete evaporation of water before leading the gases to the bag filter or to ESP.

The quantity of water required for conditioning of gases in a medium sized cement factory may be of the order of 40 tons per hour. Scarcity of water and power in many parts of the world especially near cement factories demands heat recovery from the flue gases for power generation and reduction of water consumption required for quenching the flue gases.

The conventional heat exchangers employed for heat recovery from e.g. gases in the cement industry have very low efficiency due to scaling caused by heavy dust load.

High dust concentration in the flue gases may also lead to complete choking and failure of the system.

CALDYN has invented and developped a new system THERMOWIR which makes use of a principle called MULTIWIR being practiced by

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CALDYN successfully for elimination of dust particles and droplets from the flue gases.

Fig. 2 shows the products developed by CALDYN for the scrubbing and energy technique.

Principle

THERMOWIR is designed specially to recover waste heat available in flue gases with substantial dust load. The heat transfer tubes are kept clean constantly by applying the principle of multiple cyclones. A number of small cyclones are generated within a staggered packing called MULTIWIR. A MULTIWIR-Packing consists of parallel plates which are fixed at a particular angel to the gas flow. Gas flow is divided in narrow streams which cross each other through the structured packing. As a result of the reciprocal transfer of momentum in a transvers direction in relation to the principal direction of flow the streams induce rotational motion in each other. Due to the centrifugal force, the solid particles are thrown from the center of the channel to the walls of the MULTIWIR.

The heat transfer tube (Fig. 3) is placed exactly in the middle of the channel, so that it remains almost dust free. Dust is collected at the walls and in the corners of the packing. The dust is taken out of the packing in due time intervals.

MUTLIWIR represents a combination of staggered packing and multicyclones. The number of spinning streams in practice is very large (several thousands). The vortices also increase heat transfer coefficient. The gas side pressure drop is kept within tolerable limits.

Power Generation with waste heat recovery

One of the major application of THERMOWIR is the generation of steam to drive turbine/generator sets for power generation. THERMOWIR can be successfully applied (Fig. 4) to generate steam and as a prededuster. More than 60 % of the dust can be taken out of the gases proir to the ESP.

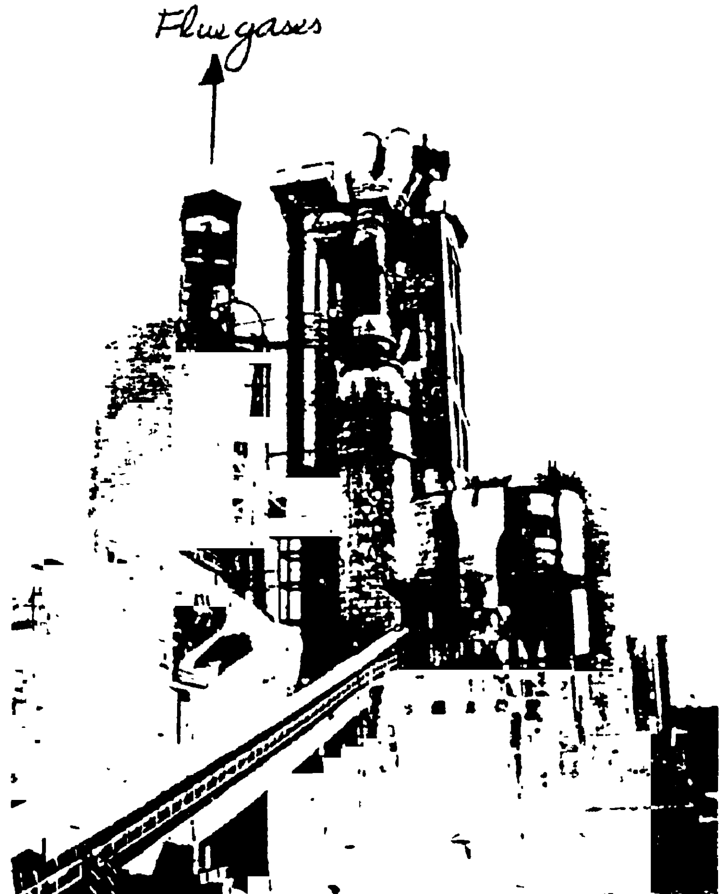
Fig. 4 Shows layout of the captive power plant for a cement factory. Water is heated to saturation temperature and a part is evaporated to steam within the THERMOWIR. An externally fired boiler and superheater is added to the system to take care of the fluctuating flue gas temperatures and to superheat the steam to the desired value of ~ 430°C.

Superheated steam at 34 bar pressure and 430° C is led to drive the steam turbine-generator unit. The T/G unit can be equipped with an air cooled condenser, thus saving huge amounts of water. Preliminary calculations have revealed that ~ 6 MW electric power can be generated out of waste heat in a cement factory of 1 million tons capacity per year. Water saving is of the order of 200.00 tons per year.

Economics of the system

A computer programme is developed to compute the pay back period for the investment required for the captive power plant (Fig. 5 and 6). The pay back period for most of the cases is less than five years.

First plant of this kind in a cement factory in India has been financed under PACER sheme by the US Government. This plant with a capacity of 2,6 MW electric with 1,6 MW out of waste heat recovery is being erected at present at DHAR Cement, Jeerabad near Indore.


Flue gases

CALDYN

Innovations for Scrubbing Technique

- Pneumatic nozzle CSL
- Spray drier ST
- Quenching tower QN
- Desulphurisation plant ABR
- Scrubber with aerosolenlargément CALWIR
- Dropleteliminator MULTIWIR

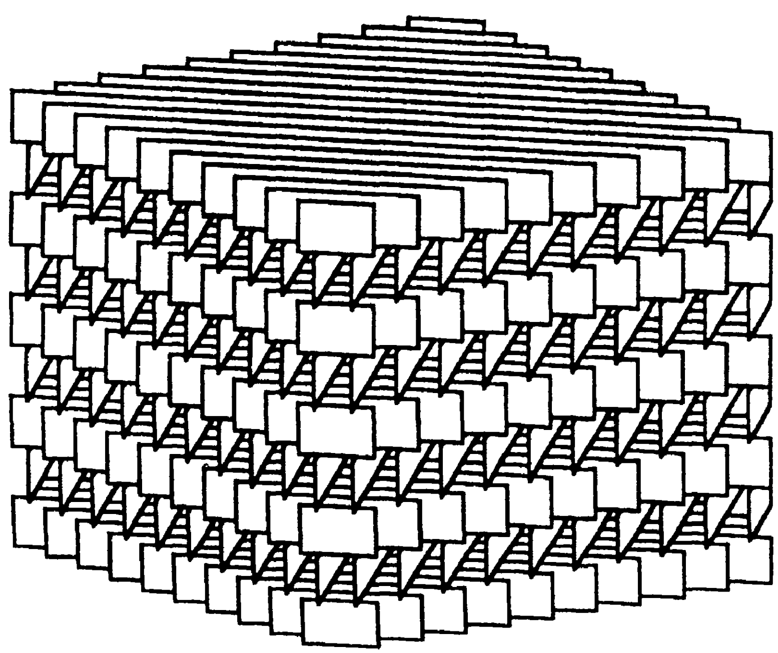
Innovations for Energy Technique

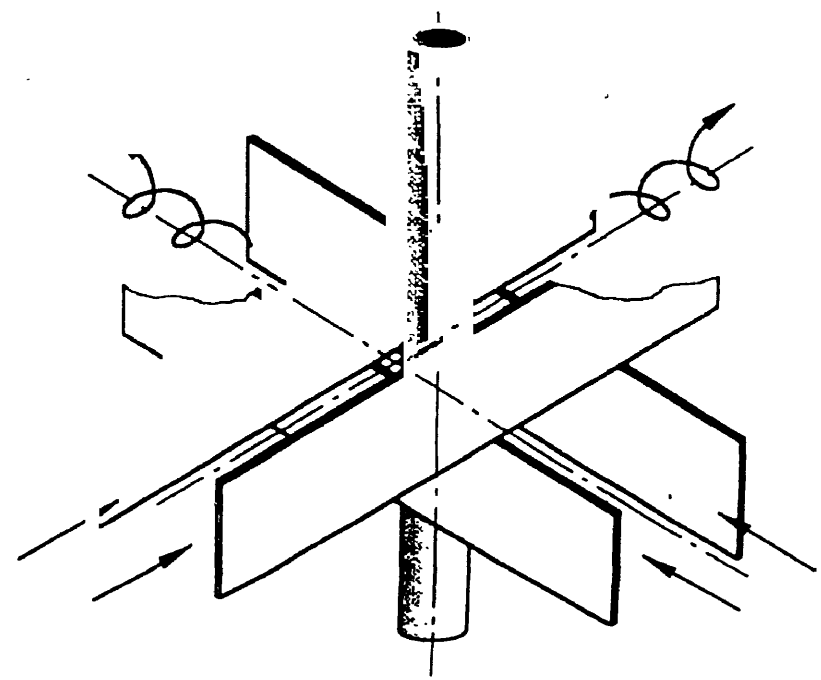
- CO_2-Evaporator CL
- Airconditioning with heat recovery FRESHERCON®
- Two stage airconditioning system for boats CLM
- Heat recovery system THERMOWIR

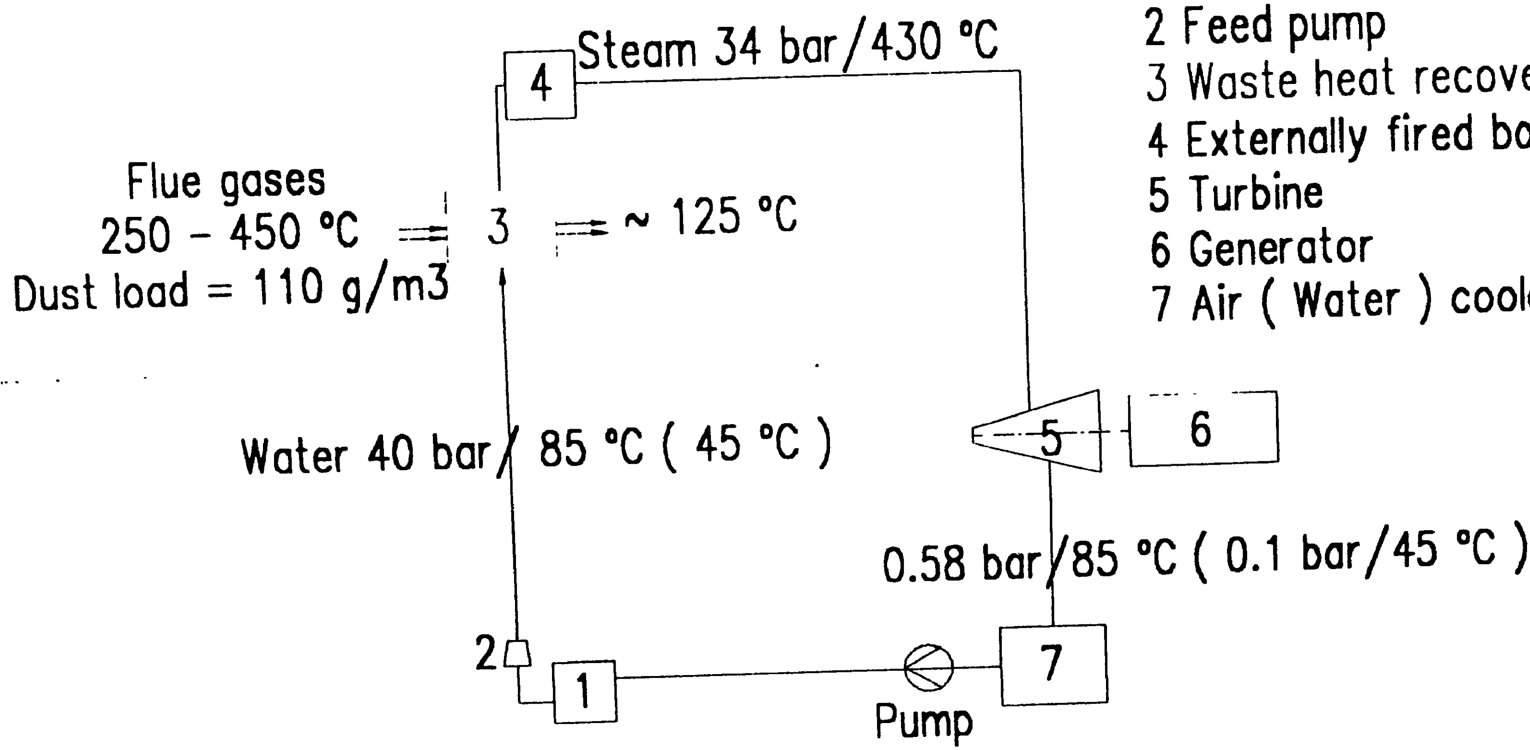
CALDYN

THERMOWIR

Waste Heat Recovery from Flue Gases with Substantial Dust Load







1 Watertank
2 Feed pump
3 Waste heat recovery THERMOWIR
4 Externally fired boiler and superheater
5 Turbine
6 Generator
7 Air (Water) cooled condenser

```
CALDYN / COM        WHR  THERMOWIR        VER 1.0

INPUT DATA                                        RESULTS

Desired power generation: 14,0 MW Electric        Water flowrate: 70000 kg/h
Gas flowrate:  227000Nm3/h                        Steam pressure: 39,8 bar
Gas inlet temp.:  380 °C                          MW height:   2692 mm
                                                  Q_1    :   0,00 MW
MW width: 14000 mm   Satur.temp: 250°C            Q_2    :  10,00 MW
                                                  Q_3    :  14,52 MW
H2O outlet temp.: 250 °C                          Q_ges :  24,51 MW
                                                  Sat.enth. : 1713,8 kJ/kg
Water flowrate:  70000kg/h                        Gas T1     : 380,0 °C
                                                  Gas T2     : 277,6 °C
Steam content outlet:  30 %                       Gas outlet temp: 125,0 °C
                                                  CP Water : 4525 J/kgK
Condenser air/water (a/w): a                      CP Gas : 1040 J/kgK

                    Heat balance OK (y/n) ?
```

```
CALDYN / COM        WHR  THERMOWIR        VER 1.0

INPUT DATA                                          RESULTS

Capital Cost:
 THERMOWIR: 14,7 Cr Rs
 Conventional boiler: 0,25 Cr Rs/MW Thermal         Temp.diff.Sat.:  28 °C
 T/G + Accessories:  2,0 Cr Rs/MW Electric
                                                    Total cost: 50,6 Cr Rs
Fuel cost: 1800 Rs/MWh Electric
Electric energy: 2800 Rs/MWh                        E-Power from WHR:  6,13 MW

Interest rate:  2,0 % p.m.                          Pay back time:  4,7 years
T/G Efficiency: 25,0 %
Desired power generation: 14,00 MW Electric
Working hours p.a.: 7200

              Cost Calculations OK (y/n) ?
```

COGENERATION FROM WASTE GASES EMANATING FROM KLIN

MR V P AGARWAL & MR K C SOOD
PRAKASH INDUSTRIES LIMITED

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

CO-GENERATION FROM WASTE GASES EMANATING FROM KILN

* V.P. Agarwal & K.C. Sood

Direct Reduction through Coal Route has now stablisied. Focus is now on optimisation of operation through recovery of Waste Heat contained in the Hot Waste Gases emanating from Kiln. In this paper special emphasis has been laid on Waste Heat Recovery & Power Generation

1. WASTE HEAT RECOVERY BOILER & POWER GENERATION

Almost 1,00,000 NM3/Hr of Waste Gases at 1000 Deg. C. emanate from 1,50,000 TPA module of DR Plant which in any conventional plant are cooled, cleaned and let off to atmosphere.

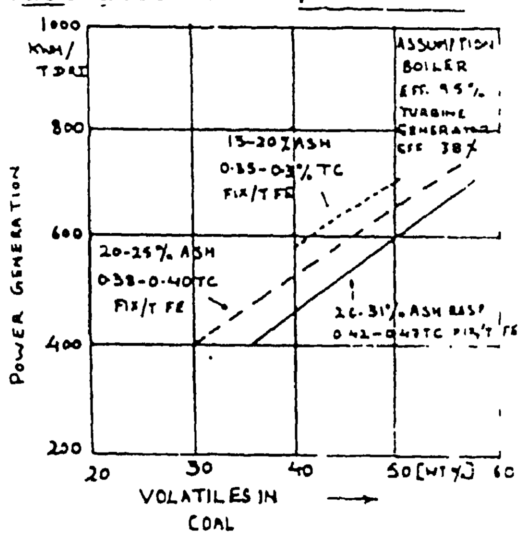
At Prakash Industries, a Waste Heat Recovery System has been incorporated to recover the sensible heat contained in Waste Gases and thereby generate steam which is led to steam turbines for generating Electric Power.

Power thus generated caters to the total electricity demand of DR Plant, the Raw Material Preparation System, for all utility facilities, offices and residential area as well as two nos. 3T Induction Furnaces.

Out of total Heat generated from Coal and reactions in DR Plant, only 35% Heat is used in reduction and the balance goes as Waste. This is a colossal waste of energy.

Obviously, the next question is as to how much electric power can be generated per ton of DRI?

Generation of Power depends on coal consumption and quality of coal fed to the Kiln. The same can be expressed in terms of fix carbon consumption per ton of ore fed into Kiln. Dependence of Power Generation on Coal quality has been illustrated in Graph-1



POWER GENERATION Vs COAL QUALITY

Thus there exists, vast potential for generating power from the Kiln Waste gases by providing a suitably designed co-generation

---

*Mr. V.P. Agarwal is Managing Director & Mr. K.C. Sood is President of Prakash Industries Limited.

Waste Heat Recovery System.

Not that one was not aware of such a huge loss of energy potential of these Waste Gases, only ISCOR, South Africa put up a Waste Heat Recovery Boiler for generating process steam, where the quality of steam is not of paramount importance. Some others also made restricted efforts to recover this sensible heat but with varying degree of success.

The major reasons inhibiting incorporation of Waste Heat Recovery Boiler in the Coal Based unit could be summaried as here under:-

A) Sponge Iron Plants wanted to concentrate on Sponge Iron making rather than other activities as process itself was at infancy stage.
B) It requires additional capital.
C) System was not tried out one and hence involved risk. Earlier trials by some units were not very sucessful.
D) There were other problems linked with Sponge Iron making:-

I) Kiln Operation is governed by process parameter & metalisation of DRI rather than parameter of Steam or Power to be generated.
II) During Start up steam quality is not suitable for Turbine application.
III) Any interruption of Kiln operation disturbs the Waste Gas generation which causes fluctuation in steam generation.
IV) Demand of Steam depends on load whereas generation of steam depends on health of Kiln & its operation.
V) Kiln Waste Gasses carry about 35 to 40 GM/NM3 of Dust particles.

In case of Waste Heat Recovery, the Boiler is at the receiving end. Kiln operation is primary and Waste Heat Recovery System is the passive partner in the combination. In normal Boiler operation, quality and quantity of Steam is controlled by boiler firing, whereas in Waste Heat Recovery System, Boiler has to operate and perform under conditions dictated by Kiln operation parameters.

During the DR Plant operation, at times there are some unstable conditions or Kiln taken on "HOLD" under which condition, the emergency cap is operated and the waste gases allowed to escape through the emergency cap and a stage of "NO FLOW" occurs to the Waste Heat Recovery System. This is then followed by the closing of Emergency Cap with the result that the entire Gases rush through the Waste Heat Recovery System, thus there is a wide variation of Gas flow from "NO FLOW" to "FULL FLOW" and vice versa. The Boiler should therefore be so designed that it can favourably respond to these wide fluctuations of the

Waste Gas flow conditions.

In any Power Plant design, one is free to select the optimum steam parameters and accordingly procure Turbo Generator. However in case of Prakash Industries, in order to restrict the capital outlay, it was decided to go in for second hand Turbo Generator and inlet conditions of the second hand Turbo Generator became governing factor in selecting Boiler parameters.

Further, during the start up and also during the period when gas flow to the Waste Heat Recovery System is under fluctuation, the condition of Steam generated varies and under these conditions the steam is not suitable to be passed through Steam Turbine. The provision has therefore to be made for condensing the entire steam thus generated. This problem has been overcome at Prakash by providing Aux. Condenser which is able to take care of up to 100% of the Steam capacity. The steam pressure is reduced in two stages of PRDS (Pressure Reducing and Desuperheating Station). In the first stage, the pressure is reduced from 40 ATM to 7.7 ATM & in the second stage from 7.7 ATM to 1.1 ATM before the steam is passed through Auxiliary Condenser, refer Sketch-3.

Despite various odds and peculiar requirements of the Waste Heat Recovery System design, Prakash ventured into incorporating a Waste Heat Recovery Boiler in the main process line.

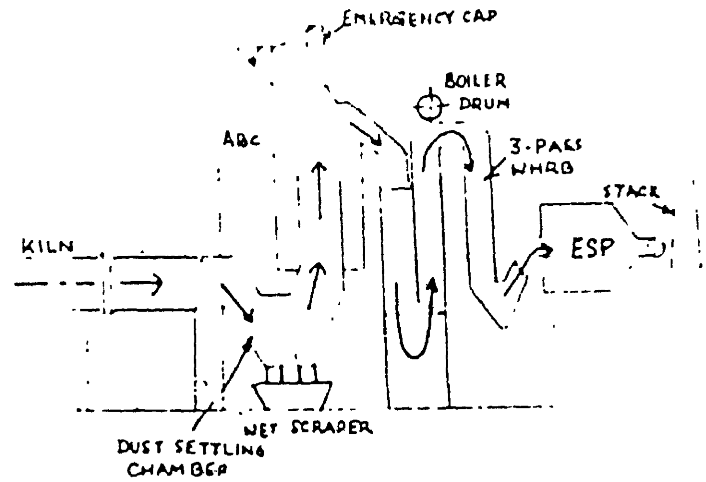


FIG. 2 Kiln with WHRB.

The Waste Gases have to be subjected to a Waste Gas treatment for conditioning with regard to its temperature, Dust Content, Combustible Constituents & Contaminants before it can be used in WHRB. Waste Gases from Rotary Kiln pass through a horizontal Dust Chamber called Dust Settling Chamber which is located beneath the After Burning Chamber ABC as shown in Sketch-2. Dust Settling Chamber reduces the Waste Gas velocity and thereby removes large dust particles by gravity, retards pressure fluctuation, achieves uniformity of Waste Gases with regard to temperature and concentration of Combutible. At the end of Dust Chamber the Waste Gases change their direction of flow and move upward in to Combustion area of ABC. A water nozzle controls the Inlet temperature of Gas. The Combustion in ABC takes place in a controlled temperature range between 950 Deg. C. to 1000 Deg. C. It

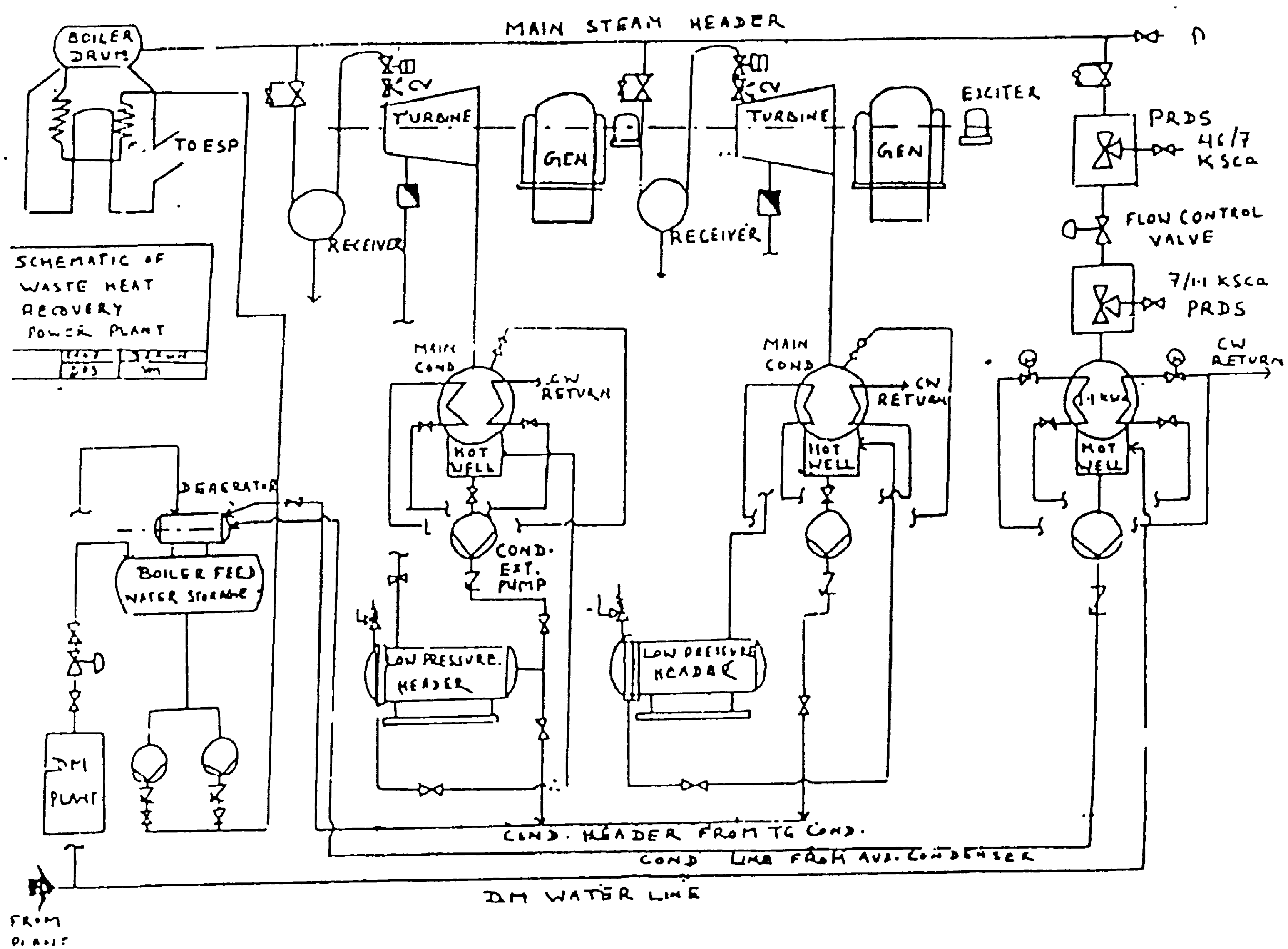


FIG. 3 : TG with Auxiliary Condenser.

is ensured that Gas leaving the Chamber has no trace of any Hydrocarbon Monoxides, Soots or Tar Components.

The Waste Gases emanating from the Rotary Kiln at 1000 Deg. C. are passed through a Waste Heat Recovery Boiler, where these Gases are cooled to 200 Deg. C. and the heat thus recovered is used to generate steam which is further used in Turbine to generate power.

The Main section of the WHRB system are briefly described below:-

BOILER

The Waste Heat Recovery Boiler (WHRB) System is a vertical, natural circulation, top supported single drum, Water Tube, three pass design. It is designed to generate Steam at the rate of 46.8 TPH; 52 Kg/Cm2; 410 Deg. C. with normal Kiln Exhaust Flow passing through the unit. However considering the present T.G. available, the Steam Pressure is limited to 45KG/CM2 at main steam stop valve with feed water inlet temperature at 130 Deg. C. During normal load, the Kiln Exhaust Gas of 96400 NM3/HR at 1000 Deg. C. is expected to pass through the unit continuously. The WHRB is also designed to generate a peak output during Kiln peak load operation. During peak load the WHRB will generate 52.9 TPH at rated condition and corresponding exhaust flow are 1,10,000 NM3/HR at 1000 Deg. C.

Waste Heat Recovery Boiler consists of the following please see Sketch-4.

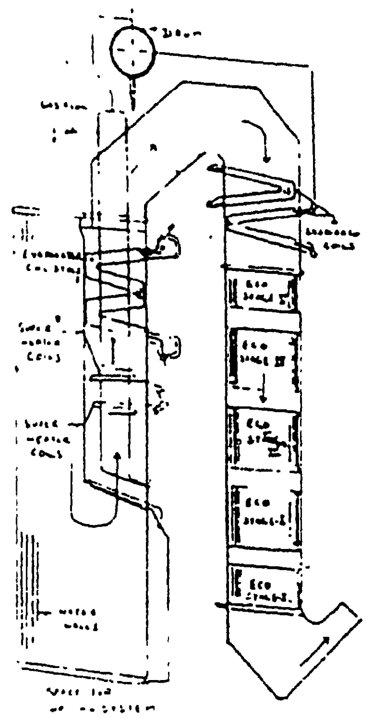


FIG. 4 Waste heat recovery boiler.

I) Water Wall
II) Super Heater
III) Evaporator
IV) Economiser
V) Steam Drum
VI) Ducts,Expansion Joints
VII) Safety Valve

WATER WALL

The Water Wall is the 1st Heat transfer section arranged in the direction of Gas flow. The entire section is made of water cooled enclosure formed by Tube fusion welded panel or fin welded panel tube. Front and rear wall are continuous and connected to top/bottom header.

The side walls are provided with headers which in turn

are connected to Steam Drum by Supply/Riser Tube.

The Furnace section is bolted buckstay for structural rigidity and suitable for negative pressure operation.

SUPER HEATER:

Super Heater-I & II are the 2nd Heat transfer section in the direction of gas flow. It consist of Plain Tube Assly. Inlet and Outlet Headers and connected links.

EVAPORATOR

Evaporator-I is located in the 2nd pass after SH-I in the direction of gas flow. It consists of inclined coils assembly made of plain tubes, inlet and outlet headers and connected links.

Evaporator II & III section are located in third pass in the direction of gas flow. Evaporator coils consists of plain tube similar as Evaporator-I.

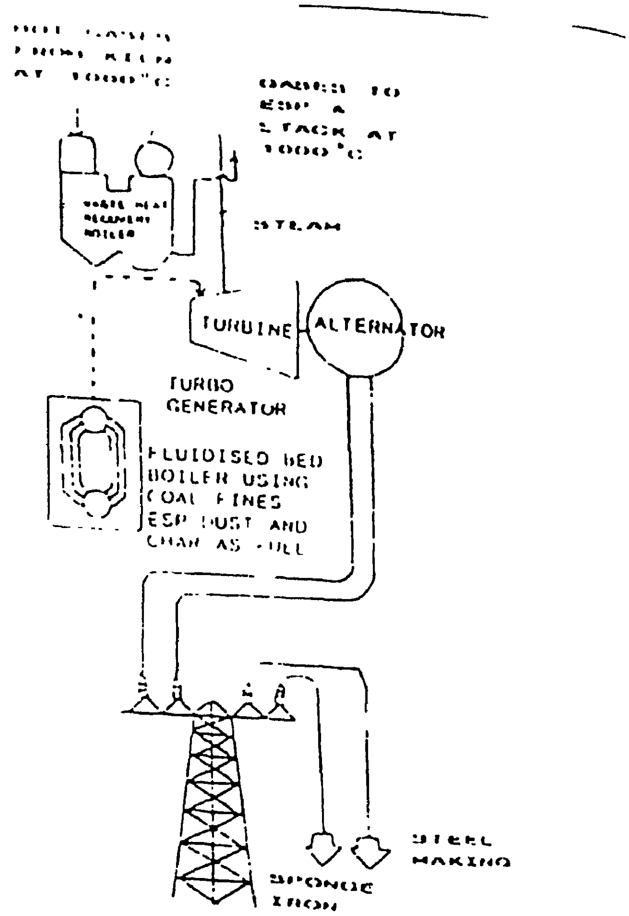
Section of gas path, Economiser section consist of plain tube assembly, inlet and outlet headers and connected links.

DUCTS EXPANSION JOINT

Suitable connecting flage with expansion joint at Boiler Inlet, Ducting with expansion joint between pass 2 & 3 and pass 3 casing Duct up to Economiser are provided.

SAFETY VALVE

Presently the Safety Valve set pressure are fixed to meet current operating condition of Steam (matching old TG Set)



POWER GENERATION FROM WASTE AND WASTE HEAT, FIG. 5

GENERATION OF POWER

Every steam generating unit is a Custombuilt. The design and consturction of modern steam generating unit involve close co-operation between many disciplines. Successful and efficient operation of the unit calls for intimate co-operation between various engineering skills. A very simple schematic view of WHRB and Power Generation is shown in Sketch-5.

AUXILIARY CONDENSER & PRDS SYSTEM

Auxiliary condenser absorb the entire steam generated from WHRB unit through PRDS (Pressure Reducting De-Superheater Station) system from the time of initial start up until a steady state operation of Rotary Kiln, WHRB is achieved. Then the TG units are put in, one by one depending on the availability of steam.

Even with two TG's on certain minimum quantity of Steam is to be passed through TG bypass circuit to

Auxiliary Condenser in order to keep this circuit in warmed up/poised state.

Keeping TG bypass circuit in poised state facilitates fast dumping of Steam as and when one or both TG units trip due to their own faults/ protections throwing entire steam as surplus. This will minimise effect of pressure surge on WHRB unit thereby ensuring its stable operation.

Similarly sudden excursion of main steam pressure due to some changes in system parameter/ malfunctioning of control element etc. in WHRB unit is not totally ruled out. Provision is made in the TG bypass control system to absorb such momentary/ sudden pressure surges by increasing quantity of dumping steam in Auxiliary Condenser. This also protects TG Sets from effect of higher Inlet Steam Pressure.

Description and operation of TG Set, close circuit of DM water, Condenser Cooling system, Electrical Distribution System, Synchronisation facilities etc. are also very important aspect of power generation through Waste Heat Recovery, but not being discussed in this paper.

IPCL's GAS TURBINE BASED COGENERATION EXPERIENCE

MR B P MARADIA
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BARODA

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

Indian Petrochemicals Corporation Limited
BARODA

Topic: IPCL's Gas Turbine Based CoGeneration Experience

Presented By: B. P. Maradia, Senior Manager, Power Plant.

Indian Petrochemicals Corporation is a major petrochemicals producing company established in 1969. It started with imported power from state electricity grid and an emergency DG set of 1.25 MVA capacity.

On subsequent expansion of petrochemical plants the need for having a captive generation was felt. During 1980-82 our electricity consumption was around 55 MW. For entire power supply we were dependant on the state grid. The power interruptions and power cuts especially during summer months were a real bottle-neck to our production targets.

IPCL went for installing 2 x 12.5 MW extraction condensing steam turbo generators during 1982. Along with the captive power generation we also installed a scheme to isolate our generation from grid whenever the latter was found unstable

The IPCL power demand rose to around 65 MW during 1987-88, with expansion of petrochemicals facilities. At that point of time a need for augmenting the captive power generation was felt. The gas turbine based co-generation was the most economical option among all the available alternatives.

Many options were available for recovering the waste heat from the gas turbines like single/dual pressure HRSG, unfired fired HRSG, duct fired/furnace fired HRSG. FD fan supported air supply v/s double capacity HRSG to continue steam generation at the same production level when one of the gas turbine trips

IPCL selected the option of dual fuel capability for the gas turbines and dual pressure HRSGs capable of firing gas as well as liquid fuel. In case one of the gas turbines trips the other HRSG can be supplementary fired to double its capacity to maintain the same level of staem production from the co-generation plant.

The alternative of going for dual pressure duct fired and doubling the capacity when one of the gas turbine trips has helped us in operational as well as maintenance simplicity, saving in the space and capital investment. Since the number of dampers between the gas turbine and HRSG is only one, the controls, protection and interlocking are very much simplified. Our HRSGs are vertical gas path and horizontal water tube type. They are with forced circulation and have external drums connected with flexible headers to the economizer and evaporator blocks. Due to modular construction HRSG erection time was reduced considerably.

IPCL opted for the 2 x GE frame 6 (36 MW ISO) dual fuel fired gas turbines with Speedtronic Mark-IV controls; 2 x 50+20 (HP-LP) T/Hr, quick start, double capacity when supplementary fired HRSGs from M/s HCG Holland. 3 x 15 T/Hr fuel oil treatment plant from M/s Alfa Lavel and distributed control and information system from M/s GE, USA (Datatronic DCIS).

IPCL commissioned and started commercial operation of the co-generation plant in May 1988. The fuel gas to our units is supplied through HBJ pipe line. On commissioning this plant IPCL has become self sufficient on the power front. our dependence on the state electricity grid has considerably reduced and power system stability has increased by many folds. We have reduced our contract demand with state grid from 65 MVA to 35 MVA. This is just enough to take care of one Gas turbine outage. The installation of isolation and load shedding scheme based on under voltage

relay to sense voltage dip of 20%; under frequency relay set to operate at 47.8 Hz. and rate of change of frequency relay (df/dt) set to operate at 1 2 Hz sec, during 1992 has reduced the incidences of total power failure to almost nil.

The co-generation plant has helped us in achieving self sufficiency, & stability with low energy index. The power stability for the petrochemical complex of our size, is extremely important not only for economic production but also for safety of the plants and personnel.

CO-GENERATION PLANT
Indian Petrochemicals Corporation Limited
BARODA

POWER GENERATION DATA

YEAR	GT#1 MWh	GT#2 MWh
1988-89	165.450	82.550
1989-90	117.450	209.570
1990-91	154.970	227.130
1991-92	258.340	196.910
1992-93	222.260	238.980
1993-94	258.680	224.830
1994 95	131.360	167.000
1995-96 (DEC)	179.990	162.690
TOTAL	1,488.500	1,509.660

TOTAL GENERATION IN MWh:

GT#1	1,488.500
GT#2	1,509.660
TOTAL	2,998.160

/

CO-GENERATION PLANT

Indian Petrochemicals Corporation Limited

BARODA

	Average	1991-92	1992-93	1993-94	1994-95	1995-96Jan	Total
GT#1 Generation MWh	214,201.6	258,148	222,260	258,680	131,360	200,560	1,071,008
GT#1 Fuel Con MSm3	64 619	77.465	64.067	80 922	42 874	57.766	323.095
GT#1 Sp. Fuel Con sm3/MWh	303.12	300.08	288.25	312 83	326.39	288.03	-
Running Hour	7,420	8,196	7,862	8,475	5,466	7,098	37,100
#1 Availability %	-	93.31	89.76	96.75	62 4	96.66	-

	Average	1991-92	1992-93	1993-94	1994-95	1995-96Jan	Total
#2 Generation MWh	201,933.4	196,707	238,980	224,830	167,000	182,150	1,009,667
Fuel Con MSm3	63.510	65.427	73.824	73.730	50.486	54.084	317.552
#1 Sp. Fuel Con. sm3/MWh	313.74	332.61	308.91	327.94	302.32	296.92	
T#2 Running Hour	7,523	7,774	8,318	7,722	7,049	6,753	37,618
GT#2 Availability %	-	88.51	94.96	88.16	80.48	91.96	-

CO-GENERATION PLANT
Indian Petrochemicals Corporation Limited
BARODA

	1991-92	1992-93	1993-94	1994-95	1995-96Jan
Steam to Grid T	869.307	865.056	891.483	601.251	715.862
Steam to Grid T	80.617	78.569	67.890	68.081	68.964
et Power to Grid Mwh	451.370	457.791	479.103	294.514	378.912
el gas to Gts Msm3	140.00	137.891	154.652	93.360	125.043
as to HRSGs Msm3	4.470	3.076	1.154	4.552	1.557
gas Msm3	150.00	140.967	160.00	94.122	130.00
lorific Value kcal/sm3	9.200	9.200	8.600	8.600	8.600

Data on grid failure & disturbances

The list of occasions IPCL electrical system could survive at time of the state grid failure or major disturbances.

S/n	Date	Disturbance
1	23.05.91	At 06.04 Hrs All incomers tripped, Voltage dip exceeding 40%, Fault at GEB Load dispatch centre.
2	28.06.91	At 08.10 Hrs tripping of 132 Kv incomers at GEB sub-station due to bus fault.
3	25.10.91	At 10.55 Hrs cascade tripping of MSEB & GEB grid. Rate of fall of frequency 1.2Hz/sec; Grid was unstable for almost 48 hours.
4	15.11.91	At 15.32 Hrs 33Kv incomers tripped on directional over current, bus fault at GEB Jambuva LDC.
5	15.06.92	At 19.28 Hrs total power failure in state
6	20.06.92	15.30 Hrs - Voltage dip exceeding 40% observed, leading to isolation. lightening arrestor failure at Nandesari sub station.
7	07.01.93	10.33 Hrs. 33Kv feeder tripping due to bottom disc of insulator failure at GEB Jawaharnagar.
8	17.11.94	Isolation on under-voltage due to tripping of IDI feeder on fault.
9	25.11.94 To 29.11.94	Under frequency isolations due to shortage of power in state grid and low frequency operation.
10	26.11.94	At 04.50 Hrs - tripping of 132Kv incomer at GEB Jawaharnagar sub-station.
11	01.12.94	11.42 Hrs Isolation due to low system frequency.
12	25.12.94	21.08 Hrs Tripping of 220Kv line at GEB Jambuva
13	14.01.95	19.13 Hrs voltage dip, Tripping of Asoj feeder at GEB.
14	20.01.95	13.57 Hrs Voltage dip due to Monkey Fault at GEB Calico feeder.
15	02.03.95	20.14 Hrs Tripping of 400Kv line at Bhillai-Kori & Jabalpur. Inter state grid disturbance.
16	10.11.95	11.00 Hrs Fault at generating station in MP resulting in cascade failure.
17	14.11.95	08.47 Hrs - Under frequency isolation due to overloading of grid.
18	30.11.95	09.42 Hrs - Under frequency isolation due to 400Kv Asoj-Indore Line tripping.
19	15.01.96	16.36 Hrs - Flashover in 33Kv Breaker of IDI feeder at GEB.

TOTAL UNITS GENERATED IN GT#2: 1.509.660 Mwh

SPARES CONSUMED DURING COMBUSTION.HOT GAS PATH AND MAJOR INSPECTIONS.

I STG NOZZLE	1 SET
II STG NOZZLE	1 SET
III STG NOZZLE	1 SET
I STG BUCKETS	2 SETS
II STG BUCKETS	1 SET
I STG SHROUD BLOCKS	1 SET
MODIFIED TP'S	1 SET
GAS ONLY NOZZLES	1 SET
DIAPHRAGM COUPLING	1 No.
HS QUILL BRG (LOAD GEAR)	1 No.
ATOMISING AIR COMPRESSOR	1 No.

TOTAL CHARGES FOR SPARES	1.980.500	$
30 % CUSTOM DUTY	594.150	$
TOTAL	2.574.650	$
EQUIVALENT RS.	79.814.150	Rs.
TA CHARGES (1,50.000 $)	4.650.000	Rs.
TOTAL Rs.SPENT TOWARDS MAINT	84.464.150	Rs.
UNIT MAINT. COST (1509660x1000)	5.59 PAISE PER UNIT	

MAINTENANCE SUMMARY

SCHEDULED INSPECTION OUTAGE GT# 1

1. Hot gas path inspection & I Stg. Bucket change out.
   Fired Hours - 27,800 hrs.

   During this inspection, the I Stg. buckets which were originally supplied along with the units were changed out as per GE's TIL No 1095-1 March 1991 & Til No. 1095-1R1 June 1991.

   Original I stg Buckets supplied were P.N 932E0147 P005 P006, as per TIL 1095-1 and TIL 1095-1R1,these buckets were failing during service due to CREEP RUPTURE STRENGTH EXACERBATED BY ACCELERATED OXIDATION ATTACK AND HIGH BUCKET METAL TEMPERATURE. This oxidation resulted from deterioration of the external coating ,and also by internal oxidation attack of the uncoated cooling holes. This oxidation contributed to local over temperature by partial plugging of cooling holes and subsequent reduction of creep life.

   We were advised to change the I Stg. buckets with new design 932E0127P043/P044, Equiaxed, GTD-111,11 hole,GT-29 IN PLUS coated buckets.The parts changed during this inspection were a Set of TP and a Set of Bull horn brackets.

SCHEDULED INSPECTION OUTAGE GT#2

1. Hot gas path inspection
   Fired Hours - 15,090 hrs.

   Except for erossion on TP photo frame and TP side seal, the general condition of Hot path components were excellent. During this outage the Field Modifications for Atomizing Air booster compressor isolation and By-pass line in atomizing air cooling water were carried out

2. Hot gas path inspection & I Stg. buckets change out (March 13th to April 15th 1992)
   Fired hours

   The I Stg buckets were changed during this outage,as per GE's TIL 1095-1R1.During Hot gas inspection the I Stg Nozzle was found to be having Eccentricity of 10mm. Cracks were found on outer side walls and vanes.The cracks and eccentricity were within the inspection criteria. Oil leak from BRG #1 was also arrested by providing new oil seal and rotor float was adjusted from 0.025" to 0.017" by changing active side Thrust shim.

3. Hot gas path inspection
   Fire hours -38,884 hrs.

   This shut down was mainly taken for changing the I Stg. Nozzle,which was not available with us during last HGP. This inspection revealed the II Stg. buckets Z seal (bucket shroud) creep deflection, and subsequent locking and overlapping of shroud tips leading to cracks at some places,(GE TIL No. 1067-3R1) It was decided to change

the same at Major Inspection. A set of Modified TP with TBC coating and flex seal (101E2572 G02 Rev.2), were replaced. I Stg. shroud blocks having cracks were also allowed to run till Major Inspection.

4. Major Inspection
Fired Hours - 47524 hrs.

I Stg buckets 109E3033 P001/P002 were installed according to GE TIL 1147-1 Jan 1994. It is 12 cooling holes, GTD-111. DS, with GT-29 In Plus coating.
II Stg buckets 979E0615 P001/P002 were installed according to GE TIL1067-3R1.
II Stg Nozzle 932E0144 G012 were installed because an extensive cracking was observed on the outer side wall.
I Stg shrd blocks 329A3228 G004 were installed.
During clearance measurements Downward deflection of III Stg Nozzle was observed and it was advised to change it during next outage. Foreign Object Damage observed on I Stg Compressor Rotor was repaired and 17th stage compressor blade spacer was stacked. (TIL 1090-2R2 Mar 1993)

5. III - Stage Nozzle Replacement

During last major inspection outage, the downward deflection of III stage nozzle was observed. Since the nozzle was not available, it was planned to change it at next convenient opportunity.
During this shutdown, III stage nozzle kit no. 948E0281G006 were installed. Alignment between load gear and gas turbine was checked.
Shell cooling fans 88TK-1,2 were taken down from turbine roof and installed outside the gas turbine building.

UNSCHEDULED OUTAGE GT # 1

The unit was commissioned on LDO on 5th April'88 and taken on gas on 14th May 1988.

1. 4th July 1989 to 28th Nov 1989
The unit tripped on false fire alarm at 11.40 hrs, due to an earth fault in fire detection system. After clearing the fault, unit was put online at 20.25 hrs. At 20.33 it tripped on over speed alarm. The inboard seal & inboard bearing of shaft #1 were found damaged. Gear box casing had developed crack in vertical direction, running downward around six inches. The investigation revealed the rolling of the shaft no. I inboard bearing, due to locking of accessory coupling which was oil filled type gear coupling from Zurn. The entire repair job including metal stitching, resleeving and assembling was carried at SPIC, SMO at their Bombay workshop.
Since shaft no. I was not available, metal spraying on journal area was done at Indore.
The unit was recommissioned on 28th Nov. 1989.

2. 11th July to 16th July 1990

Unit tripped on overspeed at 18.30 hr. The cause of tripping could not be established for a long time. Ultimately it was suspected that the spring tension on the over speed trip trigger might have reduced and the contact area for latching was not adequate. After improving contact area and increasing the spring tension, assembly was refixed and put in operation. It continued to behave well thereafter.

3. 8th October 1990 to 8th January 1991

Abnormal noise from the accessory gearbox was observed at 16.00 hr on 8th October, and before any corrective action was taken the shaft no. I and II were damaged. The gearbox was checked for bearings bore alignment and concentricity. They were found correct. The cause of failure was exactly not located but the decision was taken to replace the gear coupling with diaphragm coupling.

The unit was rolled after installing a new diaphragm coupling on 8th January 1991.

4 15th May to 17th September 1994

Unit tripped on Exhaust over temperature followed by High vibration. On investigation of the exhaust duct the hot parts debris confirmed the major failure of the gas turbine. The unit was stripped open. The II and III stage of the rotor including II and III stage of the stator were completely damaged. I stage nozzle was found intact. I stage rotor had few broken buckets. There was a rubbing damage to the first five stages of compressor stator as well as rotor stages also. The detail destructive and metallurgical investigation at GE. USA. revealed the failure of I stage buckets (GTD-111,Equiax, GT-IN PLUS 932E0127 P043/044) due to creep failure.

We had originally I stage buckets 932E0147P005/006 installed on our machine. TIL1095-1 and TIL1095-1R1 were issued to us during March and June 1991. Based on the advise given in this TIL we had changed our I stage buckets in September 1992.

Further advise came through TIL 1147-1 asking the customer to change the I stage buckets at 20,000 fired hours. Before we complete the predicted life of these buckets, the brake down took place.

The total repair job was given to BHEL including the supply of compressor stator and rotor blades and turbine II and III stage buckets.

During this outage an alignment of entire train was carried out. Generator retainer ring (18Mn-5Cr) inspection for cracks was carried out.

Unit was recommissioned on 17th September 1994

UNSCHEDULED OUTAGE GT # 2

Hydraulic filter started developing high differential pressure suddenly. The cause was attached to the leakage of lube oil cooler tube. Entire Quantity of lube oil drained and replaced. After locating the leaking tube and plugging, unit was put back in service.

10th October to 14th October 1995

High vibration observed on accessory gear box shaft #1. The gear box was opened and inspected. Thrust faces of shaft #1 and 2 were worn out. Bearings were changed on all the shafts. Lube oil pump and hydraulic pump were inspected. Unit was put back online on 14th.

GENERAL PROBLEMS AND SOLUTIONS

Load Gear compartment hot gas leak from exhaust plenum: It is a perennial problem. Requires frequent attendance. we generally pack the intermediate partition with ceramic wool blankets, which lasts till next outage.

High vibration on 88TK-1,2 : attending this fans installed over the roof of the GT was a recurring problem. GT had to be brought down to run on part load many a time, to take care of the wheel space temperature of 3rd stage during outage of these fans.
Final solution of this problem was to bring it out of GT building. This has reduced it failure frequency and it is very easy to monitor and maintain these fans.

Atomizing air cooling : when running on Liquid fuel, atomizing air circuit comes in to line putting additional load on the cooling circuit. It is observed that the air temperature to atomizing air compressor remains in the region of 135 c. Continued operation very near to alarm limit damages the atomizing air compressor. We have failure of two such compressors on each unit.
Since the fuel gas availability at our complex is more or less unintruptted, we always run on gas. We have blanked off atomizing air circuit and compressors are taken out from the circuit to avoid unnecessary running and damage.

Lube oil leakage from HS QUILL oil deflector: Load gear box high speed quill shaft deflector leakage is another nagging problem. A modified HS Quill bearing from GE, with modified oil dam with rotary oil sealing ring has almost solved this leak. Moreover, by installing additional vapour extraction fan to reduce gear box vapour pressure has helped solving this leakage from oil deflectors.

Exhaust temperature high spread in unit #2: This is a peculiar problem related to this unit which has exhaust on Right hand side (looking downstream). Due to high spread many times it had to be operated on part load or caused downtime to check & reorient or replace the fuel nozzles. This problem is seldom faced in unit #1 which has left hand side exhaust.

WASTE HEAT RECOVERY STEAM GENERATOR

On HRSG 1 there is a persistent problem of humming noise. It is causing tube vibration and rubbing with baffle plate and occasionally causing the tube failure. We, at every available opportunity tighten the holding down fixture bolts at tube bends.

EVACUATION AND UTILISATION OF 20 MW COGEN POWER - A CASE STUDY

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THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

1. Introduction

A 20 MW cogen power plant is proposed to be set up at Simbhaoli Sugar Mill. Simbhaoli is a small town located on the Delhi-Meerut-Bareilly highway and is predominantly agricultural. This town has no loads which could be classified as "industrial". Thus for the utilization of the 20 MW output of the cogen plant, a survey of the areas in the neighborhood of Simbhaoli was undertaken. Fortunately within a radius of about 30 km a growing industrial town viz. Gajraula could be located. Gajraula is a semi-urban town situated at a distance of about 30 kms from Simbhaoli and 50 kms. from Moradabad (Manjhola).The load demands are predominantly domestic. commercial and Industrial. The distribution of power supply within the city and adjoining areas is the responsibility of UPSEB. However due to the perennial power shortage in the state, the existing power supply arrangements for the industrial factories are not quite satisfactory and suffers from too many interruptions which affects the productivity of the industries located at Gajraula. Thus Gajraula appears to be an ideal site for absorption of the Simbhaoli Cogen power output which is expected to be more reliable.

2. Existing load demand

The following table shows the list of major industries in and around Gajraula along with their sanctioned loads in MVA:

Power supplied at 33 kV:

(1)	Vam Organics	8.0 MVA
(2)	J K Pharmaceutical	2.9 MVA
(3)	Insilco	2.5 MVA
(4)	Ramganga Fertilizer	1.65 MVA
(5)	Best Board	1.2 MVA
(6)	Tirupati Texnit Ltd.	1.4 MVA
(7)	J K Dairy & food ltd.	2.0 MVA
(8)	Ranauq Automobiles	0.8 MVA
(9)	Ratan Vanaspati	2.0 MVA
(10)	Sri Acid & Chemicals ltd.	3.0 MVA
	Total	**25.45 MVA**

Power supplied at 11 kV:

(1)	Kamakshi Paper Pvt. Ltd.	0.975 MVA
(2)	Kovel News Print	0.995 MVA
(3)	Shivalik Cellulose	0.950 MVA
	Total	**2.910 MVA**

3. Status of Load Demands in Gajraula Industrial Area

A quick survey of the load demands of some of the major industrial loads in the area indicated that 25.45 MVA of load is being drawn from UPSEB grid at 33 kV, and about 2.9 MVA at 11 kV. The break-up of the industrial load demand, company wise is indicated below:

Table - I

Power supplied at 33 kV.

	Name of the industry	Load max demand	Product manufacture	No. of shifts	Captive Gen.
(1)	Vam Organics	8.0 MVA*	Adhesives	3	1.5+2.5 MW DG-set
(2)	J K Pharmaceutical	1.5 MVA	Penicillin	3	2 x 1 MVA Diesel std by
(3)	Insilco	2.5 MVA	Dried Silica (for tyre industry)	3	2 x 1 MVA Diesel std by
(4)	Ramganga Fertilizer	1.65 MVA	Fertilizer	3	
(5)	Best Board	1.2 MVA	Plywood	3	
(6)	Tirupati Texnit Ltd.	1.4 MVA	Under garments		
(7)	J K Dairy & Food Ltd.	2.0 MVA	Dairy Products	3	
(8)	Ranauq Automobiles	0.8 MVA		3	
(9)	Ratan Vansapati	2.0 MVA	Vegetable oil	3	750 kVA diesel std by
(10)	Sri Acid & Chemicals Ltd.	3.0 MVA	Paper, chemicals & fertiliser	3	1160 KVA diesel std by

*Exclusive of 2 MVA steam generator output (Cogen) which supplies the works on a continuous basis.

It is seen that all the comparatively larger industries are having their own captive generator (DG sets) which serve as standby to the UPSEB grid supply and are used whenever grid supply fails. Vam Organics. however, in addition to 4 MVA DG standby generation, also have steam operated cogen plant of 2 MW capacity which meets the essential loads on a continuous basis.

As per the present tariff, approximate electricity consumption charges that the industries have to pay to the UPSEB varies between Rs 2.75/kWh to Rs 2.90/kWh.

Data regarding load variation in some of the industries were also collected. A few samples of these are at Exhibits I & II.

4. Consumer's perception regarding quality of UPSEB grid supply

Operating personnel of the factories of some of the major industrial bulk electricity consumers in the Gujarat Industrial Area were invited to indicate their views in regard to the quality of grid supply received by them from UPSEB on the basis of their day-to-day experience. All the personnel interviewed expressed the opinion that the quality of grid power supply received by them was not satisfactory both in terms of reliability as well as in terms of voltage and frequency.

As regards reliability of grid power supply, it was gathered that interruptions occurred about 15-20 times a month of varying durations. Average figure quoted regarding duration of the power supply interruptions was about 30-40 hours/month or 360 to 480 hours per year. This sort of unreliable power supply was playing havoc with their production schedules although they were not able to furnish figures regarding the impact of these interruptions on profitability of their business.

As regards quality of supply in terms of voltage and frequency, we were given to understand that during the night hours i.e between 12 A.M. to 6 A.M. normally supply voltage and frequency were good. However during the rest of the day voltage and frequency deteriorate considerably and touch their lowest values (as low as 75 to 80% of declared voltage & frequency as low as 48.5 hz) during the peak load hours from 6 pm to 10 pm. Apart from these, during agricultural season, when power supply to the irrigation

tubewells is given the highest priority by UPSEB, hours of interruptions to industrial consumers may touch a figure of 10-12 hours per day. During this season voltage also remains low almost throughout the day due to the continuous working of the low p.f. irrigation tubewell motors.

In sum, the general impression gathered on the basis of these discussions with the bulk-consumers in Gajraula was that they would welcome more dependable power supply even at a higher price if the extra amount to be paid by them is not very much higher than UPSEB grid supply rates.

5. Existing T&D System in Simbhaoli-Gajraula Area

A 220 kV grid substation of UPSEB is existing at Simbhaoli. The 220 kV Simbhaoli Grid substation gets its power from Narora Atomic Power Plant (NAPP). (470 MW) situated about 80 km from Simbhaoli over 220 kV single circuit line. The 220 kV Simbhaoli grid substation is also connected by a 50 kms 220 kV single circuit line to Meerut (Modipuram). From Simbhaoli 220 kV substation four 132 kV single circuit lines emanate for Hapur, Naglikithore, Jahangirabad and Gajraula. The industrial town of Gajrual has a 132 kV existing substation. There are two 132 kV, single circuit Transmission lines emanating from Gajraula, one towards Simbhaoli and other towards Moradabad. Normally Gajraula gets its power supply from Simbhaoli and only in case of some fault on Simbhaoli-Gajraula 132 kV section, power is supplied from Moradabad.

At Gajraula 132 kV substation, six 33 kV feeders emanate towards the following load centres :

(1) Industrial Estate
(2) Hasanpur
(3) Fazalpur
(4) Mandi Dhanaura
(5) Other Industries
(6) Rajabpur

At Gajraula S/S there are four transformers. two at 132/33 kV level of 40 MVA and 20 MVA capacity each, and two at 33/11 kV level of 5 MVA capacity each. Power from these transformers is fed into the sub-transmission and distribution system for feeding to the load centres. The total load of Gajraula is about 50 MVA. and in order to meet the

growing load demands and improving the quality of power, UPSEB have initiated work for strengthening of the transmission system by constructing another 132 kV S/C line from Simbhaoli to Gajraula. These works are likely to be completed by 1996/97.

A single line diagram of existing transmission systems in Simbhaoli-Gajraula area is enclosed as Annexure-IV.

6. T&D Options available for evacuating 20 MW cogen plant output

The available options are:

Alternative I:

(I) Sell the entire output (20 MW) directly to industrial consumers at Gajraula by means of a dedicated feeder, taking off from Simbhaoli Power Stations to Gajraula.

Alternative II:

(ii) Sell the cogenerated power to industrial consumers by using UPSEB grid- i.e. wheeling the cogen power through UPSEB grid.

The pros and cons of the above two options are discussed below.

Alternative I:

Dedicated feeder option:

For meeting the load demands of Gajraula industrial area. it is not possible to transmit this power at 33 kV as the distance involved is 30 kms which is more than the permissible limit. A 66 kV transmission is not feasible as the 66 kV voltage level is not available both at Simbhaoli and Gajraula. Moreover a minimum of two 66 kV single circuits would be necessary to supply 20 Mw power to Industries in Gajraula area.

In view of the above, the only option available for meeting the industrial load demand in

Gajraula area is to construct a dedicated 132 kV single circuit feeder with 'Panther' conductor to Gajraula costing about Rs 555 lakhs. However availability of UPSEB gird supply has to be ensured in case of any fault on the dedicated 132 kV single circuit line from Simbhaoli cogen plant to Gajraula.

Alternative II:

Option of wheeling cogen power over UPSEB Grid:

As discussed in para 5 above, UPSEB is constructing a new 132 kV S/C line from their 220 kV Simbhaoli grid substation to Gajraula 132 kV substation. These works are likely to be ready when the Simbhaoli cogen plant is commissioned. It is therefore felt that the possibility of exporting cogen power from Simbhaoli to Gajraula over this new additional 132 kV line should be explored with UPSEB, before we think of constructing a dedicated 132 kV line (Alt.I) costing about 555 lakhs.

It may be mentioned that the policy governing the charges regarding wheeling, banking etc have not yet been finalised by the UP State Government. One of the proposals that have been mooted recently on this matter contain the following salient points:

(a) "The quantity of energy specified by the developer to be wheeled out of the energy supplied at Board's substation is to be reduced by 12.5 per cent as wheeling charges to arrive at the energy received at the destination unit after wheeling".

(b) "Although energy cannot be stored in Board's grid, keeping in line with govt. policy a provision has been made for banking. The energy specified by the developer for banking is to be reduced by 12.5% as banking charges to arrive at such energy to be returned to the developer".

It will be seen from the above that these two points do not cover the case when the developer wants to make use of the T&D facilities of UPSEB for supplying its entire power output directly to industrial consumers at Gajraula.

Therefore a specific decision in regard to the advisability of constructing a dedicated 132 kV line from Simbhaoli cogen plant site to Gajraula vis-a-vis the "Wheeling" alternative cannot be taken until UP Govt spells out clearly its policy in this regard.

7. Step-up Substation at Simbhaoli & Step-down substation at Gajraula cost estimates etc.

For both the two options for supplying power to Gajraula discussed above provision has to be made for setting up a 6.6 kV/132 kV step up station at Simbhaoli cogen plant site. In the case of Alternative I, provision for stepdown arrangements at Gajraula end has also to be made.

Detailed cost estimates of the step-up station at Simbhaoli, step-down station at Gajraula and 30 km long 132 kV single circuit line from Simbhaoli to Gajraula is at Annexures I, II & III. The overall costs of these three elements are as follows :

		Rs Lakhs
i)	Estimated cost of 6.6 kV/132 kV, 2 x 12.5 MVA, step up S/S at Simbhaoli (Annexure I)	380.00
ii)	Estimated cost of 132 kV/33 kV, 2 x 12.5 MVA, step down S/S at Gajraula (Annexure II)	285.00
(iii)	Estimated cost of 30 kms long 132 kV S/C line with "Panther" conductor. (Annexure III)	270.00

The estimated cost of set up substation at 'Simbhaoli' i.e. Rs 380 lakhs would be common to both the Alternative discussed above.

8. Cost of power transmission

Alternative I Dedicated system

Assumptions :

1. Rate of interest = 18%
2. O&M and establishment = 3% of capital cost

3. Life of transmission equipment = 35 years

Capital cost of transmission & step down
Equipment (para 7 above) = Rs 5.50 crores

Annual O&M & Establishment charges @ 3% = 0.165 crores
of capital cost.

Annual overall charges = Rs [5.50 + 0.165 x 5.5386] x .1806 crores
= Rs [5.50 + .914] x .1806
= Rs 6.414 x .1806
= Rs 1.1584 crores

Alternative II wheeling power over UPSEB grid.

Cogen power generated = 20 MW
Load factor of the system = 60%

Annual energy generated = 20 x 8760 x 0.6 = 105 million units
at cogen plant

Wheeling charges @ 12.5% of energy generated
by cogen plant = 13.1 million units

Assuming overall Average cost of energy for U.P. = Rs.1.23
(1994-95 Annual review of planning commission)

Total Annual charges = 13.1 x 1.23 million
= Rs.1.6162 crores.

However this economic comparison of two alternative is just hypothetical in view of the non finalisation of a policy by UP govt/UPSEB in regard to wheeling of power by private producers over their grid.

Technically, Alternative of supplying cogen power to UPSEB grid is preferable as it would provide the requsite stability to the cogen plant.

9. Conclusion

In sum, main points that emerge from the study are :

(I) Gajraula Industrial Area only 30 kms away from Simbhaoli offers an ideal load centre for the utilisation of 20 MW power from the Simbhaoli cogen plant.

(ii) The industrial consumers at Gajraula expressed their dissatisfaction with the poor quality of UPSEB power supply (average duration of interruptions is about 30-40 hrs/month). Discussions with the consumers indicated that they would welcome more dependable power supply even at a somewhat higher price.

(iii) For transmitting Simbhaoli cogen power to Gajraula, 6.6 kV/132 kV step up arrangements have to be made at Simbhaoli (estimated cost : Rs 380.00 lakhs)

(iv) UPSEB's existing 132 kV S/C line from Simbhaoli 220 kV grid substation to Gajraula is fully loaded and does not have spare capacity available for evacuating additional 20 MW cogen power from Simbhaoli. Therefore for this purpose one alternative would be to build a 30 km long 132 kV S/C line over this section and construct a 132/33 kV step-down s/s at Gajraula. Estimated cost Rs 555 lakhs.

(v) As an alternative to the above option of constructing a dedicated 132 kV system the feasibility of making use of the second Simbhaoli-Gajraula 132 kV line being built by UPSEB (scheduled for completion in 1996/97) could be discussed with UPSEB. However it may be mentioned that UPSEB/Govt. of UP have yet to finalise their policy in regard to wheeling of power by private power producers over their grid. Unless details of the wheeling charges to be levied by UPSEB are known, it would not be possible to make an economic evaluation of the "Wheeling" option vis-a-vis the "dedicated" 132 kV line option.

Annexure I

Estimate for 6.6 kV/132 kV, 2x12.5 MVA step-up Sub-Station at Simbhaoli

Sl. No.	Description	Unit Rate(in Lakhs)	Qty.	Total Amount Rs. lakhs
1.	(a) 6.6 132 kV, 12.5 MVA Power trans. with OLTC	60.0	2	120.00
	(b) 6.6 400 V, 5 MVA transformer (including cost of 400 V switchgear & associated equipment)	15.0	1	15.00
2.	6.6 kV SF_6 breakers	3.00	3	9.00
3.	132 kV SF6 Breaker	9.00	5	45.00
4.	All switchgear other than CB's (66 kV)			
	I) 66 kV CT	0.30	6	1.80
	ii) Control & relay panel	0.75	2	1.50
	iii) 66 kV PT	0.30	3	0.90
	iv) 66 kV LA's	0.20	3	0.60
	v) 66 kV Isolators	0.25	7	1.75
5.	All switchgear other than CB's (132 kV)			
	I) 132 kV CT	1.3	6	7.80
	ii) Control & relay panel	1.5	3	4.50
	iii) 132 kV PT	1.2	3	3.60
	iv) 132 kV LA's	0.55	3	1.65
	v) Station auxiliary trans. & A.C. Dist. Box	3.00	1	2.00
	vi) 132 kV Isolators	2.00	9	18.00
		0.60	9	5.40
6.	110 Volt Battery with charger	3.5	1	3.50
7.	Structure for S/S	3.00	LS	3.00

8.	Control Cables	0.30	LS	0.30
9.	Foundation for S/S equipments	3.0	LS	3.00
10.	Misc. item such as bus connector, accessories, grounding shielding, fire fighting eqpt. S/S lighting, earthing etc.	5.0	1	5.00
			Sub-Total	**253.30**
11.	Erection & commissioning on item No.1 to 8 @ 10%			24.53
12.	Over-heads on item No.1 to 8 @ 17% I) Contingencies 3% ii) Transportation 2% iii) Vehicle (T&P) 2% iv) General establishment charges 10%			 7.36 4.91 4.91 24.53
			Sub Total	**319.54**
13.	Civil works, control room, quarters etc.			60.00
			Total	**379.54**
				Say Rs. 380 lakhs

Annexure II

Estimate for 132 kV/33 kV step-down station at UPSEB Grid substation at Gajraula

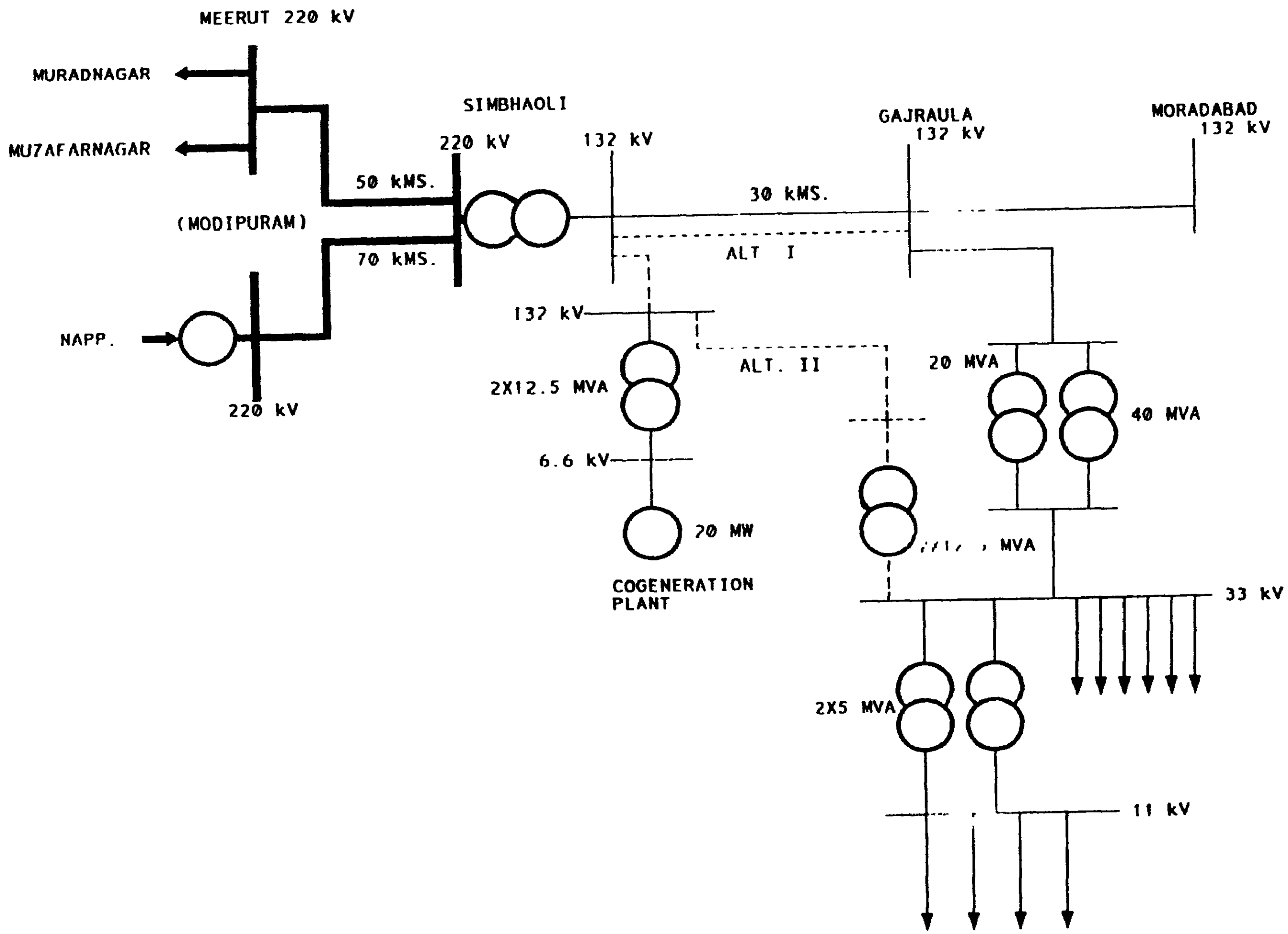
Sl. No.	Description	Unit Rate (in Lakhs)	Qty.	Amount Rs. lakhs
1.	132/33 kV 12.5 MVA Power trans. with OLTC	60.0	2	120.00
2.	132 kV SF6 Breaker	9.00	4	36.00
3.	All Switchgear other than CB's (33 kV) I) 33 kV CT ii) Control & Relay panel iii) PT iv) LA v) Isolators	 0.30 0.75 0.35 0.25 0.35	 4 1 2 2 5	 1.20 0.75 0.70 0.50 1.75
4.	All Switchgear other than CB's I) 132 kV CT ii) 132 kV PT iii) Control & Relay panel iv) 132 kV Isolators v) LA's	 1.3 1.5 2.0 2.0 0.55	 6 3 2 6 3	 7.80 4.50 4.00 12.00 1.65
5.	Structure for S/S	1.50	LS	1.50
6.	Control cables	0.1	LS	0.1
7.	33 kV SF6 Breaker	3.12	6	18.72
8.	Power cable 11 kV 3 Core 240 mm2 XLPE Cable for 11 kV breakers 100 Mtr./CB	11.0	0.1	1.10
9.	Foundation for equipment	0.5	LS	0.5
			Sub total	**224.3**
10.	Erection & Commissioning on item No.1 to 8 @ 10%			23.43

11.	Overhead on item No.1 to 8 @ 17% I) Contingencies 3% ii) Transportation 2% iii) Vehicle (T&P) 2% iv) General Establishment charges 10%			 6.73 4.49 4.49 22.43
			Total	**284.87**

Annexure III

Estimate for erection of 132 kV S/C line per K.M with Panther Conductor (130 sq.mm)

Sl. No.	Description	Unit	Unit Rate (in Lakhs)	Qty.	Total Amount Rs. lakhs
1.	132 kV S/C Galvanised steel structure self-supporting tower	NO.	0.80	4	3.20
2.	"Panther" ACSR Conductor (130 sq. mm.)	KM	0.70	3.10	2.17
3.	Insulators (Nos/km). Suspension/strain sets	Nos.	0.04	15	0.6
4.	Earthwire	KM	0.16	1.0	0.16
5.	Hardwares and accessories for conductor	NO.	0.050	12	0.6
6.	- do - but for earthwire	LS	0.06	LS	0.06
				Sub Total	**6.79**
7.	Erection and commissioning on item 1 to 6 @ 10%				0.7
	Overheads on item No.1 to 6 @ 17% I) Contingencies - 3% ii) Transportation - 2% iii) Vehicle (T&P) - 2% iv) General Establishment charges - 10%				 0.2 0.14 0.14 0.7
				Total	**8.67**
					Say Rs. 9.0 lakhs



SINGLE LINE DIAGRAM OF SIMBHAOLI-GAJRAULA AREA

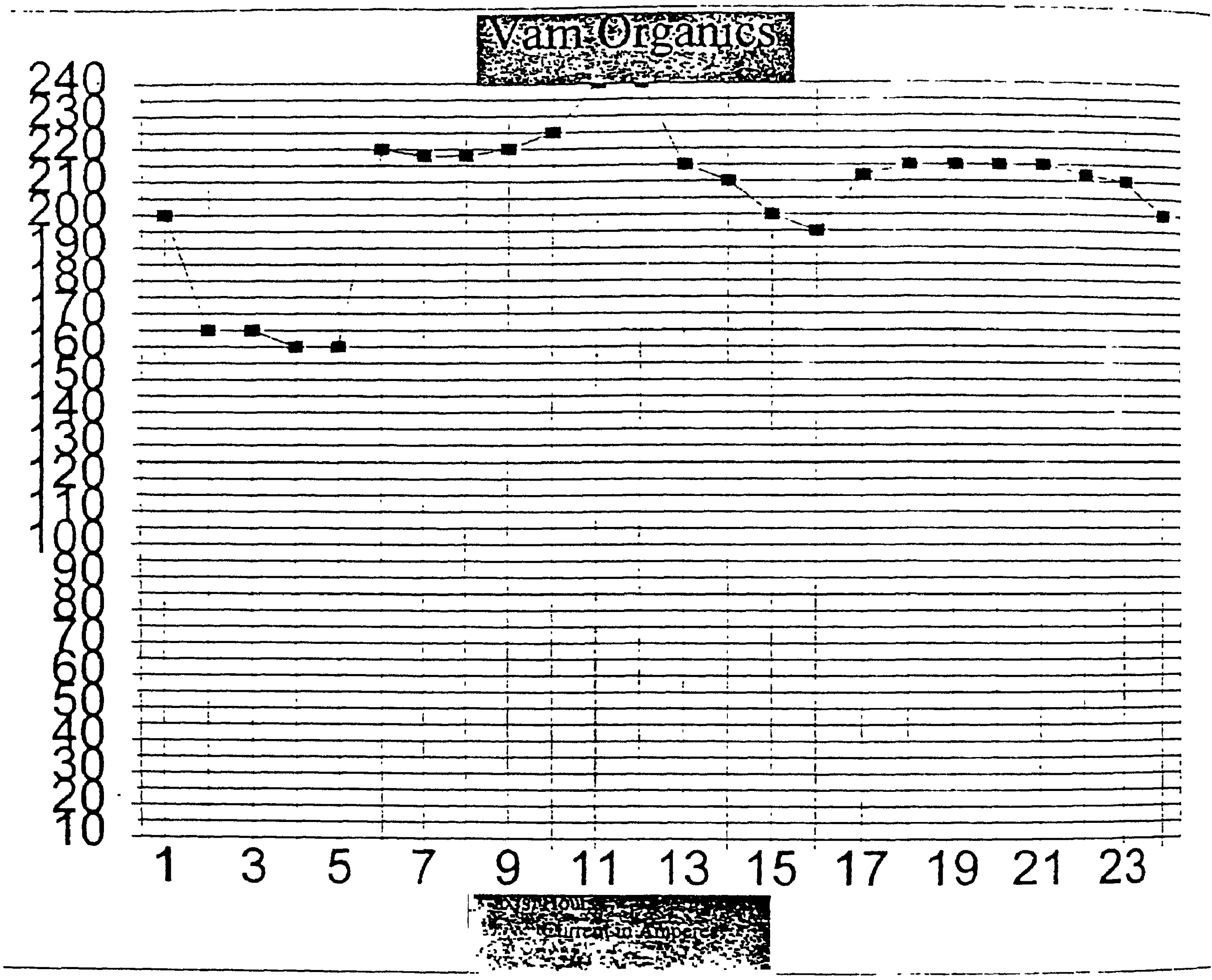
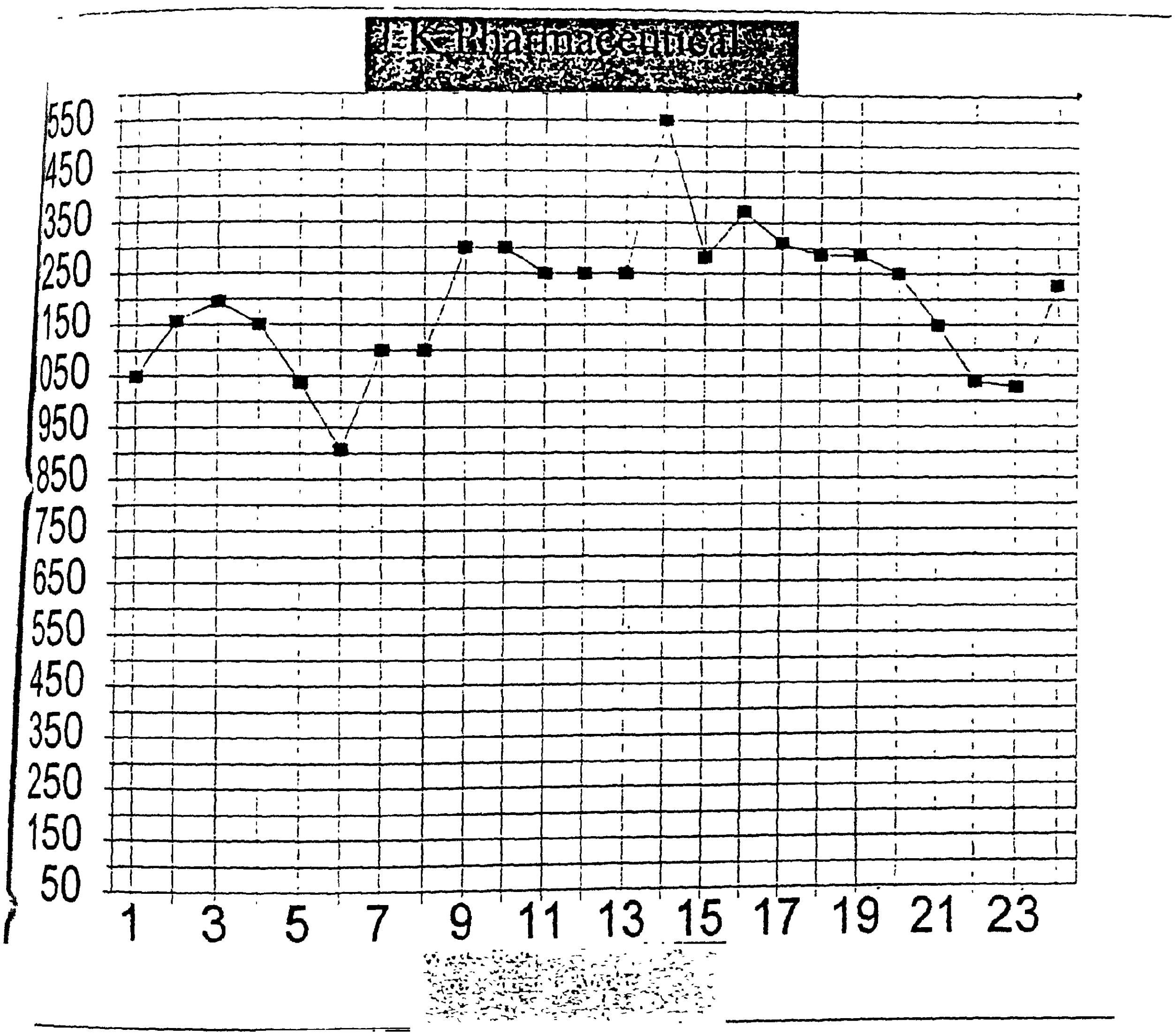

Vam Organics
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Exhibit - 11


LK Pharmaceutical
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850
750
650
550
450
350
250
150
50
1 3 5 7 9 11 13 15 17 19 21 23

BRIEF BIOGRAPHY OF FACULTY

A.	Name	:	M S BHALLA
B.	Qualifications	:	Bsc Engineering (Electrical)
C.	Organization	:	TERI
D.	Present position	:	CONSULTANT
E.	Past positions/affiliations	:	Director (Power System Planning) Central Electricity Authority. About 30 years experience in EHV Transmission Planning and was responsible for planning the evacuation system for various generating stations within the country as well in the neighboring countries.

F. Membership of professional bodies/organisations

-
-
-

G. Awards, distinctions & achievements:

- Finalisation of Transmission system of Eastern and North Eastern Regions for 8th and 9th plan conditions corresponding to various generation scenarios.
- Planning of the Transmission system associated with Tala (1050 MW) and Wangchu (900 MW) Hydro Electric Projects in Bhutan.

HIGH PRESSURE BOILERS FOR BAGASSE BASED COGENERATION

MR C V KRISHNAN & MR P RAM BABU
EID PARRY (I) LIMITED

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

HIGH PRESSURE BOILERS FOR BAGASSE BASED COGENERATION

AT

EID PARRY (I) LTD., NELLIKUPPAM

INTRODUCTION

The sugar industry in India is presently undergoing major technological changes. There are two (2) significant changes that have had major influence on the operation of the sugar plant, viz., "the employment of high pressure boilers" and "reduction on the process steam consumption". Both these changes have helped sugar plants to make a significant contribution towards cogeneration. The energy crisis and the need to improve energy efficiency have made the sugar plant designers to look at critically the fuel value of bagasse. High pressure boilers have demonstrated that how effectively additional exportable power could be generated in sugar plants. The high pressure steam technology being different to what the sugar plant designers and operators are used to heretofore, needs special consideration during the stages of design, manufacturing and commissioning. Realizing the potentials of bagasse based cogeneration, EID Parry is currently installing a 24.5 MW bagasse based cogeneration plant in their sugar factory at Nellikuppam in Tamil Nadu. This paper presents an overview of the cogeneration project at EID Parry and the high pressure boilers being installed.

EID PARRY (INDIA) LIMITED - BACKGROUND

EID Parry (India) Limited is more than 200 years old company discharging their responsibilities to the society with strong commitments to ethical values and beliefs and the history of Parrys is a saga of growth and dynamism. Established in the year 1788, Parrys today, are engaged in a wide galaxy of diversified activities. The company is engaged in the manufacture and marketing of fertilizers, seeds, plant protection chemicals, sugar industrial alcohol, sanitary ware and electronic goods. The sugar factory, owned by the company at Nellikuppam in Tamil Nadu, has a chequered history and is proud of being one of the oldest sugar plants in the country.

PLANT OPERATION - EXISTING SCENARIO

This plant has a present crushing capacity of 5000 Tonnes of Cane per Day (TCD) and operates on an average of 205 days in a year. The process steam consumption is around 55% on the cane crushed and the plant's live steam cycle is at 15 Ata and 240 Deg.C. The sugar plant operates with six (6) mills and a shreadder. Two (2) of the mills are driven by DC Motors and the rest of the mills and the shreadder are driven by steam turbines operating with an inlet steam parameter of 13 Ata and 240 Deg.C. The steam generation capacity of the plant from a battery of five (5) boilers is 145 TPH. There are three (3) back pressure turbogenerator sets generating an aggregate

electrical capacity of 6 MW. The power generated is wholly consumed by the sugar plant and the distillery and there is no surplus power available for export.

PLANT OPERATION - FUTURE SCENARIO

EID Parry has embarked upon a programme of mordernization and energy conservation in the sugar plant. This modernization programme is well under way and under this programme the balance of the mill drives and shredder drives will be converted to DC / Hydraulic Drives and AC drives respectively, the crushing capacity of the plant will be enhanced to 5200 TCD and the process steam consumption will be brought down. Under this programme, EID Parry has also taken up the implementation of Cogeneration.

STEAM GENERATION SCENARIO IN INDIAN SUGAR INDUSTRIES - HITHERTOFORE

The cane sugar plant generally is self reliant in power and bagasse, the fuel needed for the generation of steam and power. Till the last decade, the Boiler which supplies the vital inputs of steam and power to a sugar plant did not attract much attention. Typically, the mills employed low pressure boilers operating at 14 or 21 Kg/Sq.Cm with superheater temperatures going upto 350 Deg.C. This steam was expanded in back pressure turbo alternators to produce the plant's requirement of power and the back pressure steam at 0.8 Kg/Sq.Cm was used to meet the process requirements. Over the years, in the last decade, there has been a progressive increase in the boiler operating pressures in the sugar mills. In the mid eighties, the sugar plant standard specification recommended boilers with an operating pressure of 32 Kg/Sq.Cm(g) with the superheater outlet temperature at 380 Deg.C. In the late eighties some sugar mills opted for boilers operating at 42 Kg/Sq.Cm(g) with 400 Deg.C Superheater outlet temperature. The basic reason for such upgradation has been the improvements made in the process side to bring down the steam consumption from the then prevailing figure of around 60%, and efforts in this direction got a major thrust becuase of the Government policy for incentive which demands that the total steam consumption should be brought down to less than 50% on cane. This technological change resulted in the mills saving bagasse, the excellent renewable energy source. The right step in adopting the high pressure boiler technology opened up new interesting vistas like cogeneration and power export or bagasse saving for paper production.

DEVELOPMENTS IN COGENERATION IN INDIA

Cogeneration has been a subject of interest to the Indian Industry and specifically to the Government of India and this interest is born out of the fact that the sugar plant cogeneration holds the promise of narrowing the ever widening gap between the power supply and demand at low incremental cost and with short gestation. A few points which gives fillip to cogeneration are:

a. The confidence among the Industry and Operators in operating high pressure boilers

b. The enormous saving in bagasse consequent to steam consumption reduction

c. The emphasis on reducing the greenhouse gas emissions

d. The possibility of increased revenue to sugar mills

The Indian Sugar Industry's interest on Cogeneration was kindled with the encouragement and financial incentives offered by the Government of India, and the willingness on the part of State Electricity Boards to purchase this power at reasonable Tariffs. Many sugar mills in India today are looking at Cogeneration with much more seriousness and a few mills have gone ahead implementing Cogeneration. EID Parry is one such company where the Cogeneration Project is in an advanced stage of implementation.

AN OVERVIEW OF THE COGENERATION PROJECT AT EID PARRY

The Cogeneration Project at EID Parry will be mainly based on bagasse as the fuel with the boilers also designed to operate on Neyveli Lignite. There will be two (2) boilers each with a capacity of 70 TPH with outlet steam parameters at 67 Ata and 485 Deg C. There will be a single extraction cum condensing turbogenerator with a nominal capacity of 24.5 MW under extraction cum condensing mode. The cogeneration cycle is designed with a high pressure feed water heater, heating the boiler feed water from 105 to 140 Deg C The plant is designed with all auxiliaries and sub-systems required for the efficient operation of the plant. During the cane crushing season, the gross power generation will be 24.5 MW. With an internal consumption of 10 MW, the net exportable power to the TNEB grid will be 14.5 MW. It is also planned to operate the cogeneration plant during the off-season either with excess bagasse generated in the plant and purchased bagasse from nearby sugar mills, or with other bio-mass fuels like cane trash rice husk or with lignite. With adequate quantity of bio-mass fuel available, the operation of the plant for a period of more than 270 days are planned. Under the off-season operation, the plant will be exporting a net output of about 22 MW to the TNEB grid. The total project cost is estimated to be 680 Million Indian Rupees. This project is expected to be commissioned during Aug/Sep 96.

HIGH PRESSURE BOILERS AT EID PARRY COGENERATION PROJECT

BASIC DESIGN AND SIZING:

The cogeneration plant at EID Parry will have two (2) boilers each with 70 TPH capacity with the feed water inlet temperature of 105 Deg.C. With the feed water temperature raised to 140 Deg.C in a high pressure feed water heater, these boilers are capable of giving an output of 73.5 TPH each. The steam parameters at the boiler outlet will be 67 Ata and 485 Deg.C with the tolerance on the superheat temperature at $\pm$ 5 Deg.C. When EID Parry took up the plant design, there were two (2) important points which confronted the decision making. One is, the selection of Single Boiler Vs. Two Boilers and the other one is the selection of the operating parameters. These two (2) points were deliberated in detail and EID Parry took a decision of going in for two (2) boilers knowing fully well the slightly extra cost involved in going for two (2) boilers. The deliberations on the question of selecting the single boiler Vs. Two boilers, specifically in the Indian Sugar Industry, will continue for ever, but EID Parry's decision to go in for two (2) boilers was mainly from the slight, nevertheless additional, flexibility the two boiler configuration offers in the sugar plant operation.

With regard to the cycle parameters, detailed analysis have been carried out and the outcome of such analysis is that for the capacity of the boilers planned, the additional benefits of extra power generation with higher cycle pressure and temperatures are not commensurate with additional investment involved. Also, it was decided that with the present level of operation in the sugar industry, and with the stringent requirement in the feed water chemistry, it is better to limit the parameters to 67 Ata and 480 Deg.C. It is also worth mentioning that these are the widely used parameters in the sugar industry, worldwide.

DESIGN CONSIDERATION:

The boilers are of bidrum design, top supported with balanced draft operation. The boiler design adopts membrane wall construction eliminating usage of large quantities of refractory. This design affords a better control over the excess air operation of the boiler. The evaporative sections of the boiler are constituted by the furnace and a large boiler bank area. An adequately designed economiser recovers a substantial part of the heat from the flue gases making up most of the sensible heat addition requirements. The boiler is provided with an airheater which recovers further heat energy from the flue gases and ensure that the flue gases leave the boiler at 160 Deg.C. The boiler is designed with two (2) stages of superheaters. One section is a convection section and the other one is a radiation section. The surface areas of the radiant and convective sections are proportioned to give an almost flat characteristics in the operating range. In addition, there is an interstage desuperheater which controls the outlet steam temperature well within $\pm$5 Deg. of the rated temperature.

The boiler is designed for outdoor operation and is top supported on steel structurals. Adequate access stairways and platforms are provided for the easy operation and maintenance of the boiler.

Operating on bagasse the boiler efficiency will be 69.4% on the gross calorific value of 50% moisture bagasse.

FUEL FIRING SYSTEM:

The boiler is primarily designed for burning bagasse as the main fuel. The combustion system incorporates a travelling grate stoker, pneumatic distributors, a bagasse storage silo with extraction feeders and screw conveyors. The bagasse silos are designed for storing 15 minutes requirement of bagasse at MCR operation. There will be four (4) pneumatic distributors, distributing the bagasse on to the travelling grate. This firing system is also capable of handling other bio-mass fuels such as cane trash, rice husk and groundnut shells.

In order to ensure that the operation of the plant is continuous, which will result in uninterrupted power supply to the grid, lignite from the nearby Neyveli mines is thought off as an alternate / supplimentary fuel. Under situations, where there is a shortage of bio-mass fuels, provision of the lignite firing system will ensure that the agreed quantum of power will still be exported to the grid Even though the boiler is presently provided with the lignite feeders and distributors, the complete lignite handling system and bunkers will be added shortly.

ENVIRONMENTAL CONSIDERATION:

Keeping in mind the environmental considerations and in line with the values and beliefs the company cherishes, Electro Static Precipitators are being installed as the flue gas cleaning system, even though installation of this system increases the capital investment to a greater extent. Each boiler is designed with two (2) Induced Draft Fans, two (2) Forced Draft Fans and one (1) Over Fire Air Fan. Considering the possibility of lignite usage as a fuel and based on the possible SO_2 emissions under that conditions, the chimney has been designed for a height of 92 M. There will be a single chimney catering to the requirements of both the boilers.

INSTRUMENTATION AND CONTROL:

Considering the safety and operational efficiency of the plant, EID Parry has gone for the State of Art instrumentation system with Distributed Controls.

FEED WATER MANAGEMENT:

An elaborate feed water management system is planned since the boilers will be using condensates from the sugar plant. The sugar plant supplies two (2) types of condensates, one (1) is the condensate from the turbine exhaust steam supplied to the process and the other one is the vapour condensate generated in the process. Almost all the exhaust condensate will be used as boiler feed water. However, conductivity measurement and automatic bypass of the condensate to the house condensate tanks is provided to ensure that there is not even the slightest chance of contamination of the exhaust condensate. For the boiler plant operation, the exhaust condensate is not adequate and hence some amount of vapour condensate or fresh DM Water will also be required. The attempt will be to use the vapour condensate mainly from the point of view of energy conservation. Since the possibility of contamination of the vapour condensate is more likely, in addition to the instrumentation and control provided for the conductivity measurement and automatic bypass of the condensate to the drains, a system of batch tanks and testing of each batch for its fitness, for boiler feed is provided. In the case of continued contamination of vapour condensate, it is planned to use DM water as make-up. A DM Water plant with two (2) streams each with a capacity of 20 TPH is being installed to meet the make-up water requirements.

MAN-POWER TRAINING:

Considering the fact that the high pressure boilers are different from the low pressure boilers to which the boiler operators are accustomed to, an elaborate operator training, in addition to recruitment of experienced engineers and supervisors, is planned.

LAYOUT CONSIDERATION:

One of the most important point in the design of the cogeneration plant, specifically in an operating plant, is the location of the cogeneration plant within the sugar plant premises. Considering the fact that the plant will be commissioned during the middle of a season, [illegible] taken to locate the plant in such a way that its construction or

commissioning does not interfere with sugar plant operation. It is proposed to retain the existing steam and power system of sugar plant, till such time the cogeneration plant stabilizes.

CONCLUSION

With the need to conserve energy and the thrust given to renewable energy sources, the sugar plants have the greatest potential to contribute to the country's power grid. This has made the introduction of high pressure boilers, in the sugar industry, imperative. EID Parry's high pressure boiler will go into operation during the third quarter of this year. A good feed water management system and reliable instrumentation and control system are required for the safe and efficient operation of these boilers. Having commissioned many super thermal power stations with much higher boiler operating pressures, the Indian engineers and technologists have the capability to build and operate the high pressure boilers in the sugar industry.

INDUSTRIAL NEGOTIATING WITH REGARD TO SETTING UP CO-GENERATION PLANT - SIMBHAOLI EXPERIANCE

MR SATWANT SINGH
THE SIMBHAOLI SUGAR MILLS LIMITED

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

INDUSTRIAL NEGOTIATING WITH REGARD TO SETTING UP CO-GENERATION PLANT - SIMBHAOLI EXPERIANCE

BACKGROUND

Bagasse-based co-generation for power export to the grid had long been a subject of discussion between ISMA and the Government of India. In a review of the country's non-conventional energy, the Department of Nonconventional Energy Sources (DNES) had considered bagasse based co-generation of power as one of the major options. Consequently, a number of agencies in the private and public sectors had shown keen interest in it.

Simbhaoli started talking about co-generation through ISMA with DNES and its representative was placed on one of the sub-committees for submitting recommendations to the Govt. of India for setting up co-generation projects. However, the progress had been very slow because at that time, discussions only centered around deciding how sugar mills would co-generate, what type of equipment should be permitted and what concessions should be allowed. A controversy was raised by the Indian manufacturers of turbines and boilers that no imports should be allowed and only indigenously made equipment should be used. The stand what Simbhaoli took was, different - when we were willing to pay the price we wanted the best available equipment in the world market. This scenario was eight years before. It was told to the Government agencies that co-generation for a sugar mill was not new. Every sugar mill has been co-generating for its own use from the very beginning. Sugar mills did not generate more, because there was no market.

The technology for bagasse co-generation for export of power is well-known and commercially practiced in several countries, notably Australia, Cuba, Dominican Republic, Mauritius, Reunion (France) and the United States (Hawai). The gestation period for such projects is less than that for conventional thermal or hydro power plants. In India, given adequate market opportunities for power sales, bagasse co-generation projects appear an attractive investment option, capable of adding to the utility's supply capability while reducing reliance on scarce public funds. For sugar mills, bagasse co-generation projects could result in added income from electricity or surplus bagasse sales and lower production costs in downstream mill activities

Major constraints

Despite these potentially significant benefits to the economy and the proven success in other countries, a bagasse co-generation project selling surplus power to the grid is still to be realised in India. There are several reasons for this:

There is no clear cut Government policy on co-generation of power for export. Although the Electricity Supply Act, 1948 has been amended, but it has been done in a half hearted manner. It needs further revision to direct the State Electricity Boards to follow a uniform long term policy.

The U.P. State Electricity Board and for that matter all the State Electricity Boards consider sugar mills' co-generation as an encroachment in their sphere of activity. At one stage the UPSEB had categorically stated that they had surplus power and therefore the sugar mills in the State should concentrate on manufacturing sugar and should not try to meddle in power generation.

Another reason had been lack of confidence on the part of sugar technologists to handle high pressure boilers due to condensate problems.

With appropriate investments, an existing sugar mill should normally be able to export about 40 kwh of electricity per tonne of cane processed. In a maximum electricity configuration, the co-generation of electrical energy incidental to the process steam flow is augmented by electrical energy obtained from the steam generated by burning all the excess bagasse.

SIMBHAOLI - CO-GENERATION PROJECT

Present Position

At Simbhaoli, the Co-generation of power by the sugar plant for supplying to the Grid, as a viable proposition was considered about a decade before, after completion of a study by the World Bank on the possibilities of setting up co-

generation plants in the sugar units in the State of Maharashtra. A complete techno-economic analysis had been conducted by the Simbhaoli Sugar Mill at that time on the viability of the Co-generation of Power by the sugar plant. All our expansion and modernisation plans were targeted for eventual co-generation for commercial purposes.

At Simbhaoli, following difficulties have been experienced in the implementation of the co-generation project for generating additional power for export:

a) The generation of electricity was highly controlled, as the Electricity Supply Act, 1948 made it almost impossible for the private entrepreneurs to set up small generation capacities.

b) The biomass/bagasse based co-generation, as a renewal energy source, was not being encouraged by the Government of India, as it had thought, paper as the only usage of surplus bagasse.

c) Setting up of any plant and machinery in sugar plants was required to be approved by Directorate of Sugar, Ministry of Food, Govt. of India and any deviation in the configurations of key equipments other than the standard list drawn by the Government, was difficult to pursue.

However, after the liberalisation, the Government has thrown open the electricity and power generation to the private

sector and Electricity Act has been amended. The Department of Non Conventional Energy Sources has also become active and started encouraging generation of power by using non conventional and renewable energy sources. The power generation by the sugar mills has proved to be very attractive for the Department of Non Conventional and Renewable Energy Sources, because of its enormous potential and lower generation cost. Further bagasse as a fuel was available in abundance with the sugar plants, who have been traditionally burning it in inefficient manner. The location of sugar plants in rural areas was also an added advantage.

We in Simbhaoli have started our co-generation project by ordering a 77 tonnes boilers of 43 ata pressure 427°C temperature with Thermax Babcock and Wilcox Ltd. In addition to that, a 12MW Power Turbine of back pressure type was ordered with Farmatome-Thermodyn Division, France. These equipments were ordered, taking into account the potential of generation of surplus power to the extent of 7 MW/hour during the crushing season and also for utilising part of power and steam to meet our expanded crushing capacity. At the same time the Company had started discussions with State Electricity Board of Uttar Pradesh for declaring a suitable policy for purchase of power generated by the sugar plants. The UPSEB has taken a long time for getting convinced about such generation, and ultimately to purchase of such power and came out with a Power Purchase Agreement. This PPA, still needs a lot of

modifications, but considering the favourable attitude of UPSEB on the entire matter it is hoped that changes will come in due course of time.

In structuring the proposed project, a conservative approach is taken by the Simbhaoli Sugar imposing an IRR of 18% on the total project cost in analysing the project. This requirement is satisfied based on the investment programme of approx. Rs.380 million in the current phase and Rs.370 million in future with the generation for approx.4800 hrs. in a year. The idea is to go into the electricity maximising configuration. The total power exported to the grid could be upto 4.24 million MW/hr in the first phase and 7.8 million MW/hr. Based on this the cost per MW of generation works out to Rs.31.25 million/per MW hour.

Negotiation with International parties

The interest of the international parties towards the Bagasse based co-generation projects was felt in the year 1993; when the Union Government has started opening up the power sector for private entrepreneurs and foreign participants. Delegates from the various countries started arriving to India. The visit of U.S.Secretary of power Ms.Hassel O'Leary was very important in this context, as with her a number of industrial corporations from United States came to India with the intention to form Joint ventures in the areas of power generation including non conventional and renewable power.

The interest was tremendous at that stage and after the discussions SSML has been considered as potential Company for setting up a co-generation plant. The Simbhaoli was one of the two sugar mills to sign an MOU. The concept of Carbon Credits and the zero impact of bagasse based generation plant on the environment was also advocated. The proposed project with international tie up is essentially an investment programme to upgrade the sugar plant at Simbhaoli whereby it enables the production of electricity and bagasse over and above internal mill requirements. The basic investment in plant would typically involve :

(a) addition of a high-pressure boiler of 43kg/cm sq.

(b) addition of a topping turbo alternator with inlet steam pressure of 43 kg/cm sq.

(c) installation of a bagasse drying system which uses waste heat from the boiler flue gasses,

(d) modification of the mill's electrical system to enable inter-connection with the UPSEB grid and supply of surplus power and

(e) process alteration and new equipment for steam savings

The SSML has looked this opportunity of JVC as vehicle for fast growth in this area on account of the following reasons:

a) It can provide technical support with regards to generation of steam generation, management of steam, generation of power and interfacing with the grid.

b) It can provide necessary capital as the sugar mill can direct its resources into expansion and modernisation of sugar and other operations.

c) The utility companies proposing the Joint Venture were more experienced in generation of distribution of power.

d) The sourcing of the equipments can be much better with international parties as one of the promoter.

The initial upbeat mood, could not be sustained for long and only committed parties were left in the race on a later date. At that time, the corporations from Europe, Australia etc. have also started showing their interest. In case of Simbhaoli as against 7 members originally participating in the U S Consortium, only two members were left.

The international parties while looking at the co-generation project in India considered bagasse as fuel for the proposed plant and made the following observations.

1. These projects under foreign participation are to be implemented in a separate company other than sugar mill and it is important to keep the project cost at a very low level in the initial period and expand that gradually over a period of time. The setting up of the project in a separate company is warranted for facilitating the investments into Equity by the inter national parties. It shall also lead to the five

years tax holidays for Electricity generation companies, as provided under the Income Tax Act 1961.

2. Some generation in the off-season is possible by saving and storing the bagasse. However, it calls for very effective bagasse storing and management system.

3. The UPSEB has set up a standard agreement for all the bagasse based generators and it is not ready to agree for a different agreement other than the one drawn by them for sugar plants. The standard Power Purchase Agreement is for five years only.

4. The possibility of the third party wheeling is less, as the sugar plants are generally located in the areas far away from the industries and setting up independent transmission system is not feasible.

Therefore, only following alternatives can be considered by the Co-generation companies to sell power.

a) To sell to the UPSEB under the general PPA drafted by it for bagasse based co-generation.

b) To wheel the power to other factories within the same group

c) To bank the power for the off-season usage by the sugar plant.

d) To invite the power intensive factories for setting up their unit adjacent to the Sugar Plant, by ensuring regular supply of power to them.

From our experience it is suggested that international parties must consider the following issues, while entering into Joint Venture with Indian Companies for setting up co-generation power plants.

1. These projects under international participation are to be implemented in separate company other than sugar mill and it is important to keep the project cost at a very low level in the initial period and expand that gradually over a period of time.

2. The orders for the plant and machinery must be placed on global tender basis, so that the best possible terms of supply as well as financing can be obtained.

3. The international participants should look into the long term viability of co-generation plant as the demand for power in future shall always exceed the supply. Power supply price increase in power supply rates in future shall be high because of less subsidising of power by the Government (The overall tariff will go up). The power department of the state has already taken a decision of not subsidising the power by UPSEB any further, in future.

4. The sugar mill shall be an independent Company and it must have interest in the power company by way of substantial shareholding, because its operations are largely dependent upon the power and steam to be generated at co-generation plant. Further the induction of a co-generation plant should positively contribute towards the sugar mills financials.

5. As a test case, the international parties can look into setting up of a power intensive units for consuming the power at the site itself, adjacent to the sugar plant for maximising the revenue and hedging all possible risk.

Enclosures

1. Flow of sugar manufacturing process at SSML
2. Schematic flow design of steam cycle of SSML
3. Power generation and steam balancing at Simbhaoli for 1995-96 sugar season
4. Power generation and steam balancing at Simbhaoli for 1996-97 season
5. Power generation and steam balancing at Simbhaoli for 1997-98 season

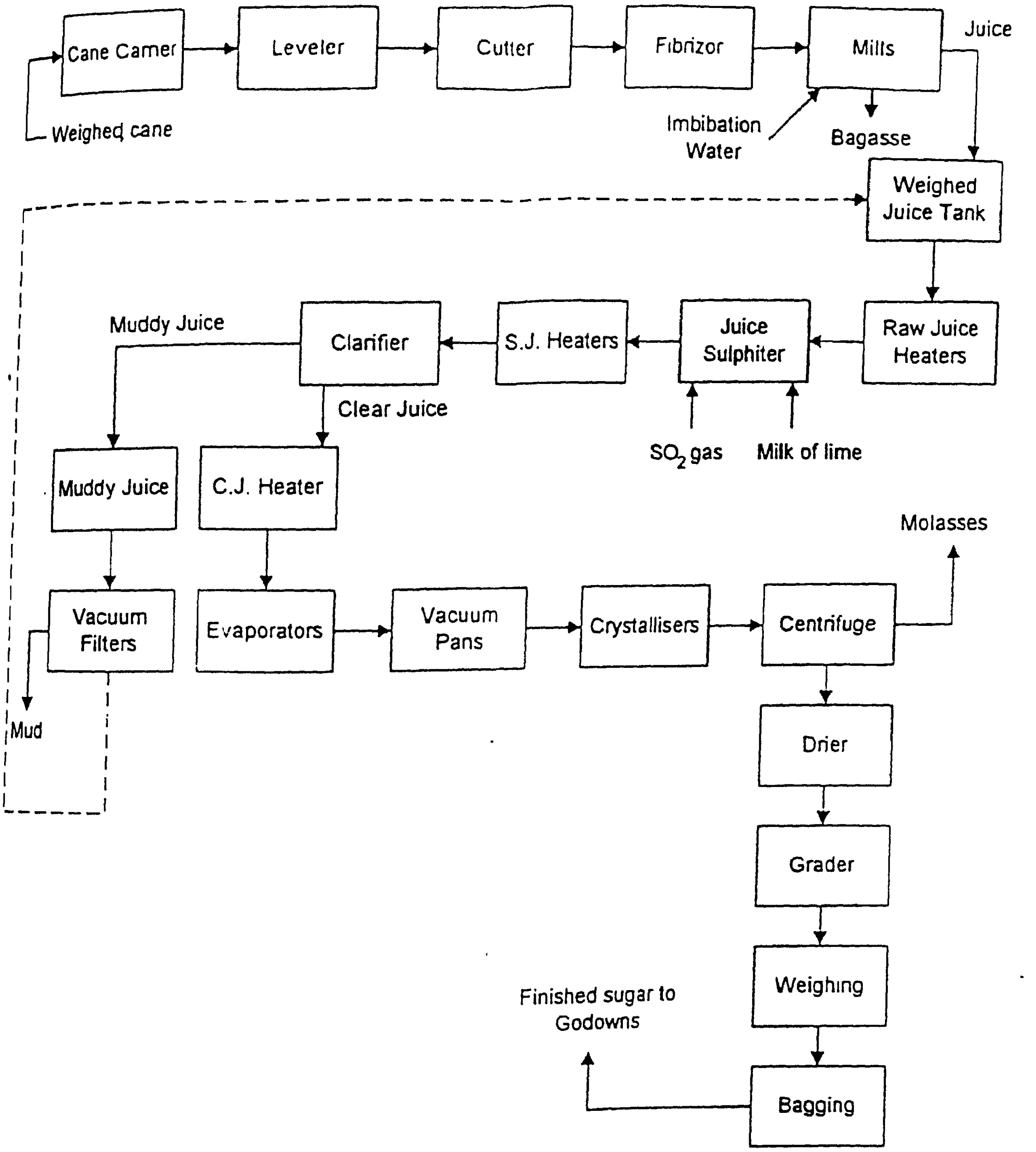


Figure 1: Simplified flow of sugar manufacturing process at SSML

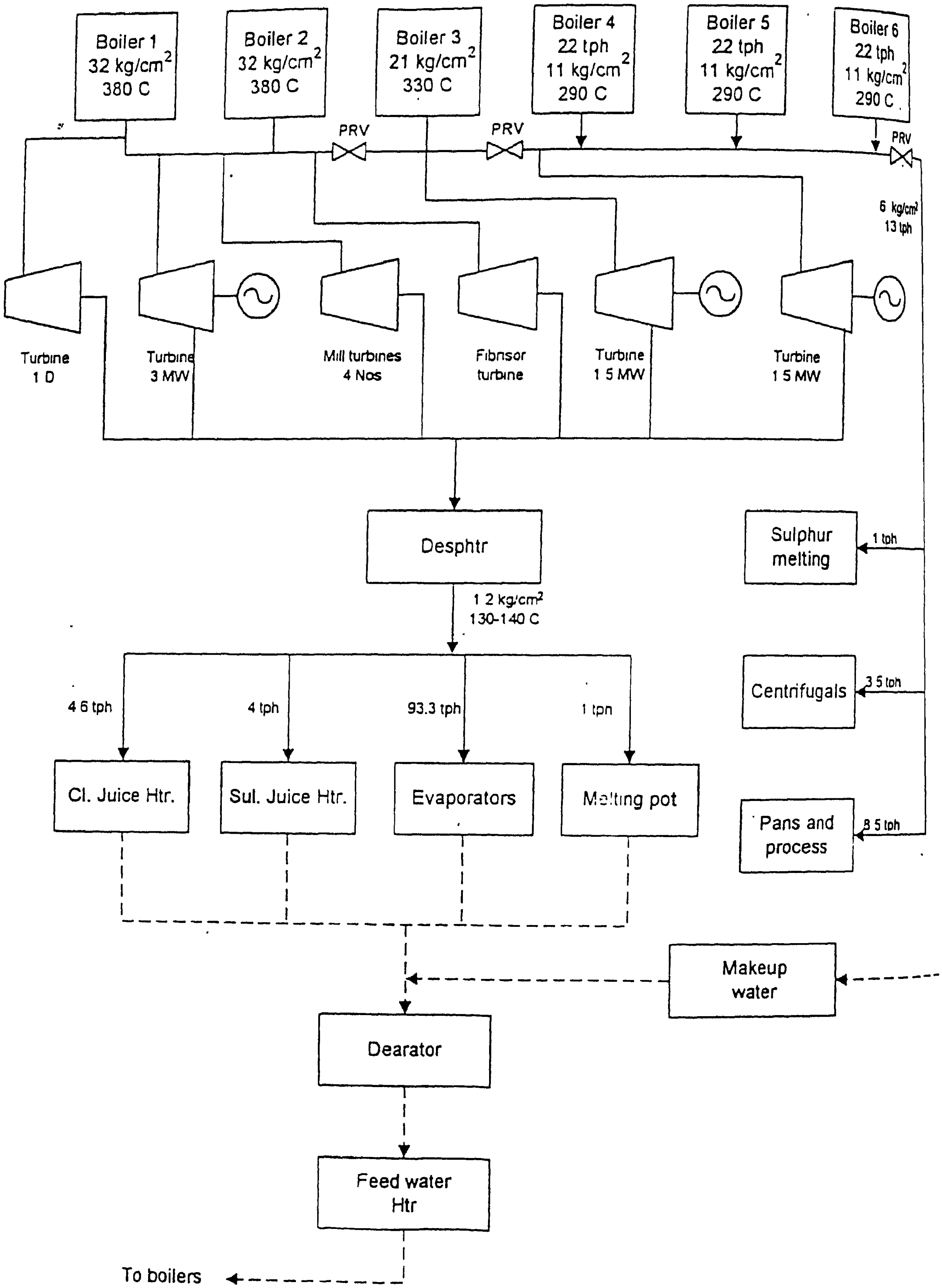
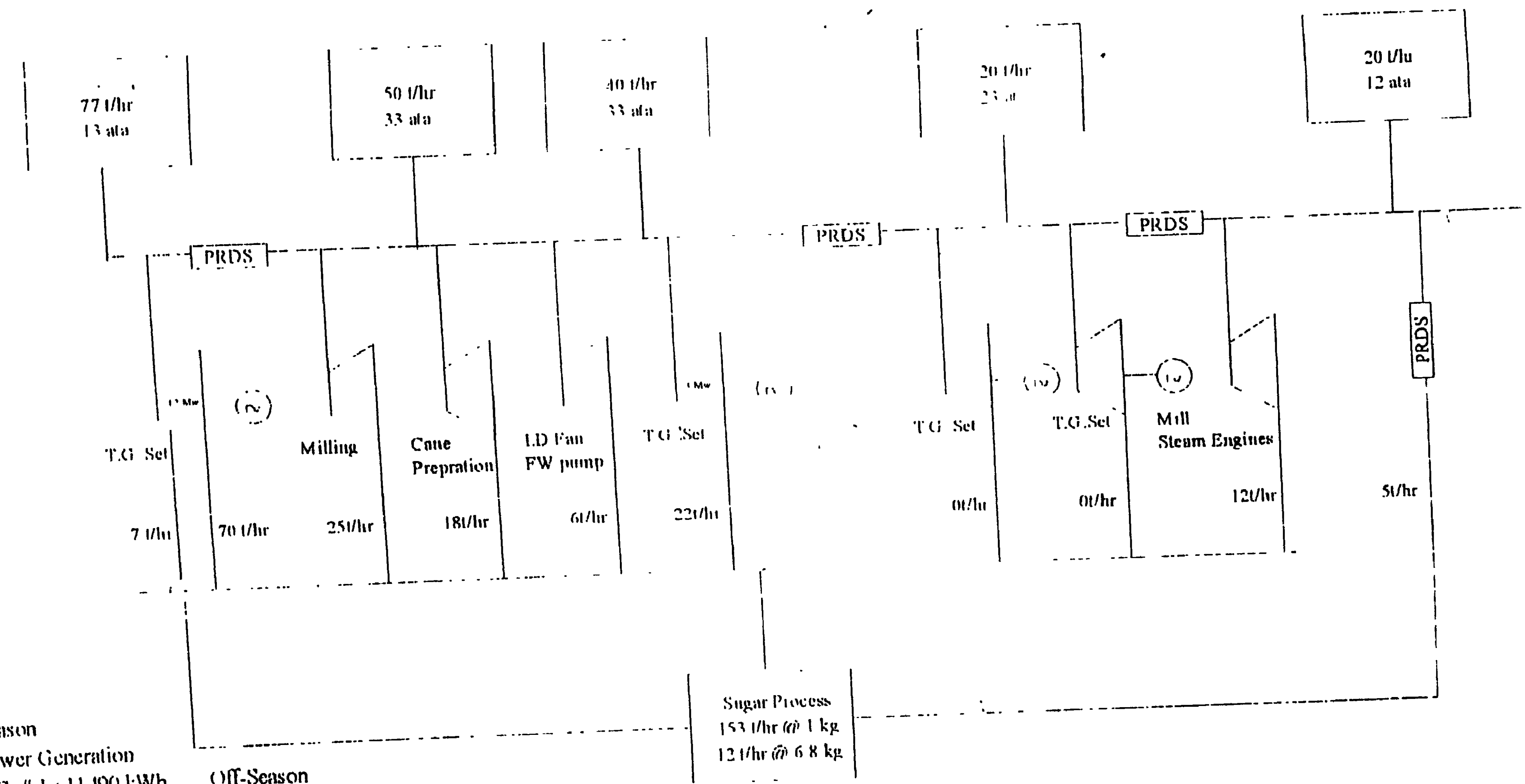


Fig. 2 Schematic flow design of steam cycle



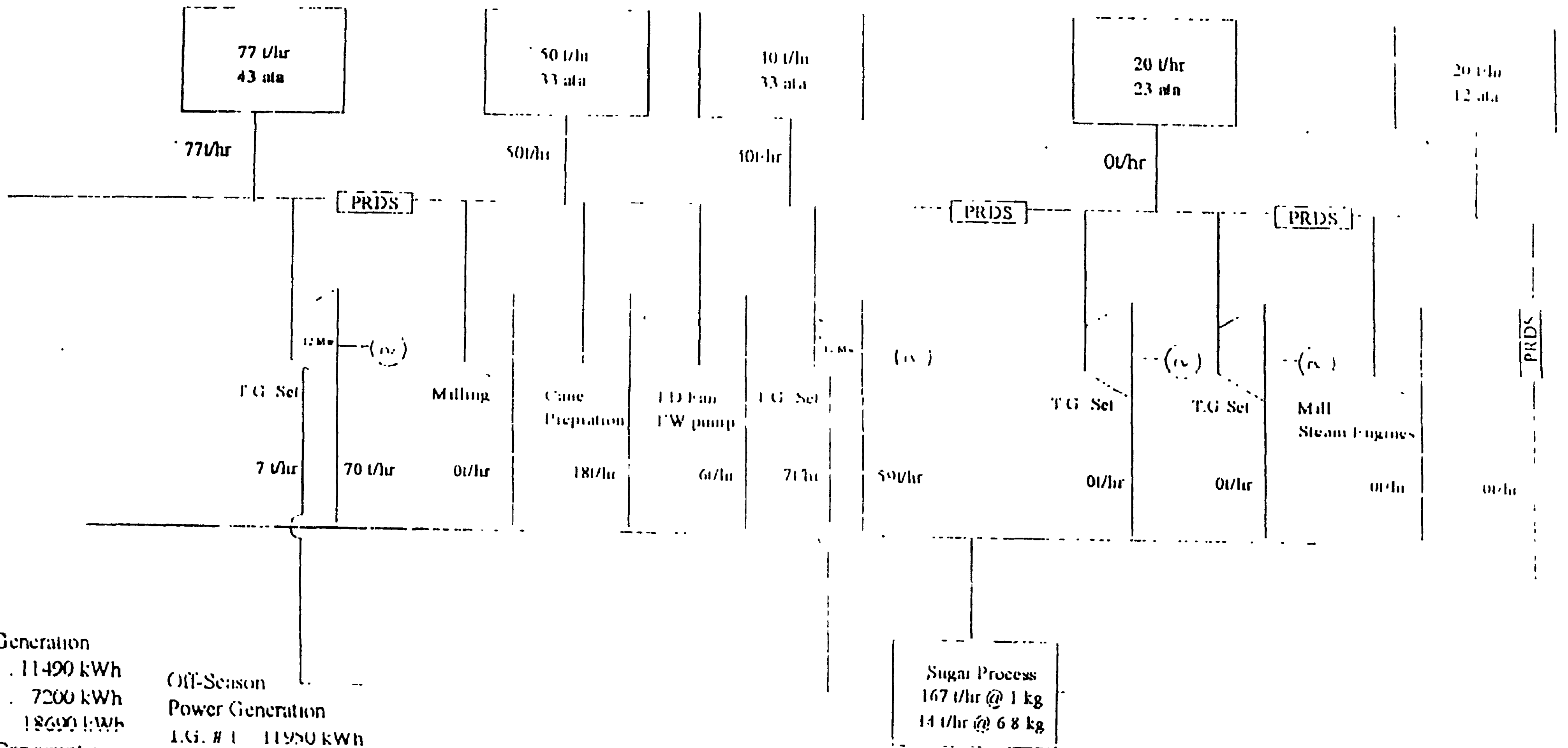
Season
Power Generation
T.G. # 1 : 11490 kWh
T.G #2 2700 kWh
TOTAL 14190 kWh
Power Consumption
Factory 7000 kWh
I.V 620 kWh
TOTAL 7620 kWh
Surplus Power
6480 kWh

Off-Season
Power Generation
T.G. # 1 : 11950 kWh
Power Consumption
Factory . 1500 kWh
I.V . 620 kWh
TOTAL . 2120 kWh
Surplus Power
9830 kWh

The Simbhaoli Sugar Mills Ltd.

(During Operating Hours)

Phase - I (upto 340 TCH)

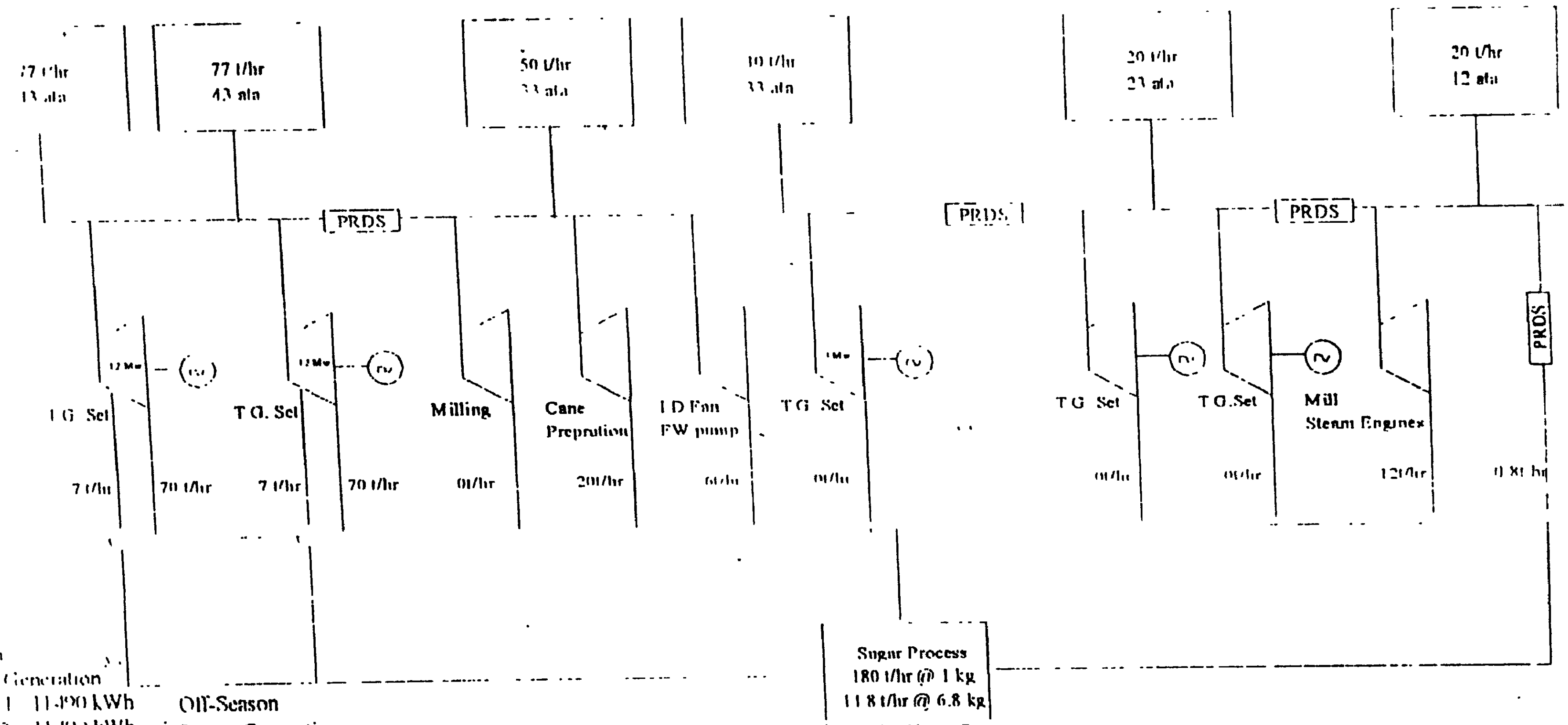


Season
Power Generation
T.G. # 1 . 11490 kWh
T.G. #2 . 7200 kWh
TOTAL 18690 kWh
Power Consumption
Factory : 7 000 kWh
J.V . 620 kWh
TOTAL 7620 kWh
Surplus Power
11070 kWh

Off-Season
Power Generation
T.G. # 1 11950 kWh
Power Consumption
Factory : 1500 kWh
J.V. : 620 kWh
TOTAL 2120 kWh
Surplus Power
9830 kWh

The Simbhaoli Sugar Mills Ltd.
(During Operating Hours)

Phase - II (@ 400 TCH)



Season
Power Generation
T.G # 1 11490 kWh
T.G # 2 11490 kWh
TOTAL 22980 kWh
Power Consumption
Factory 9500 kWh
J.V. 1240 kWh
TOTAL 10740 kWh
Surplus Power
12240 kWh

Off-Season
Power Generation
T.G # 1 : 11950 kWh
Power Consumption
Factory : 1500 kWh
J.V : 620 kWh
TOTAL 2120 kWh
Surplus Power
9830 kWh

BAGASSE BASED CO-GENERATION OPTIONS IN INDIAN SUGAR INDUSTRY

DR G C DATTA ROY
TURNER MORRISON GROUP

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

BAGASSE BASED CO-GENERATION OPTIONS IN INDIAN SUGAR INDUSTRY

- G.C.Datta Roy*

Introduction

Number of study has been carried out under the auspices of several nationa' a-: interanational agencies to identify the bagasse based co-generation investme-- opportunity and steps required for commercialising the same in the Indian Suga- Industry. The author who has been involved in Co-generation operation for 25 years and also in sugar operation for over 5 years was associated with a consortiu- of International Consultancy organisations for one such study conducted for Asia- Development Bank. Some of the interesting observations made during the course of operating experience and also while pursuing the consultancy assignment on the subject are presented in this paper. The presentation has been arranged as under

- Co-Generation Potential
- Perception of benefits-risks.
- Development of Co-generation options
- Techno-economic consideration and decision process
- Conclusion

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Co-Generation Potential

A figure of 3500 MW is currently in circulation as possible potential based on a study of an MNES Task force. The potential depends upon several variables like :

- Sustainability of area under cane and cane yield
- Fibre content in cane
- Milling efficiency
- Factory energy efficiency
- Energy conservation measures including bagasse drying.

Based on summary assessment of the current operation level and sustainability fac... the statewise co-generation potential has been estimated under two different sets ... efficiency conditions (Annexed Table 1 & 2)[1] as under:

- 2800 MW at higher efficiency level.
- 1400 MW at lower efficiency level.

At this time it is really not important whether it is 1400 MW or 3500 MW or higher ... issue should really be on how quickly can each and every factory realise its ... potential.

Benefits - Risks

Several factors like perceptions on Risk-Rewards, Inadequacy of institut... arrangement, fluctuating fortune of the Industry, Technical and Infrastructural ... etc. have been responsible for relatively slow progress so far (though some mome... seems to have picked up in the last 2 years, thanks to efforts by MNES). Accord... author's perception there is a need to further educate all involved in Sugar en... on understanding of the enormity of the rewards and various options available ... minimising the risk, particularly risk on sugar operation. This would help in ... acceleration of the process.

Benefits

The principal elements of rewards for investment in bagasse based co-generation ...

- Improved sugar economy - reduced earning fluctuation
- Low cost / Low gestation Investment.
- Positive environmental impact

Indian Renewable Energy Study - ADB TA No 1953 IND

Sugar Industry and consequently the sugar farmers periodically go through deep depression on account of price volatility as a result of agro-climatic conditions and Governmental Control Worldwide. Variation due to agro-climatic factors is practically beyond control. It is also anticipated that GATT/WTO will not have any significant impact on Governmental Control over this industry.[2] Thus, one of the way the industry can maintain relative stability in the long run is by reducing revenue dependance on sugar. Unfortunately in India, barring one factory in South, the revenue from by-products for almost all the factories are less than 10% (Table 3)[3].

Table 3 - Revenue from sugar & by-products

(Rs. in lacs/year)

Sl.No.	Average Revenue sales of sugar	Revenue from sales of by-products	
		Amount	% age of total
1	9101	244	2.68
2	9204	499	5.42
3	9236	342	3.70
4	10510	398	3.78
5	9414	193	2.05
6	na	na	-
7	8962	252	2.81
8	8592	685	7.97
9	9105	677	7.43
10	na	411	-
11	9872	na	-
12	9009	2239	24.85
13	10099	28	-
14	8739	588	6.73
15	8765	960	10.95
16	8236	277	3.36
17	9180	156	1.67
18	9234	878	9.51

Except for company No. 12, for rest earning from by-product is less than 10%

2. Sugar - Winning in a corrupt market - CSR, Australia.

3. Benchmarking study for the sugar industry - 93/94 - NPC/Indo-German Interfirm comparison project.

In one study carried out by the author (1995) for two factories in Bihar, it has been estimated that revenue from Co-generation can be close to 40% of the gross revenue (Annexed table 8 & 9). Thus, even a price variation of 10% in sugar would not have more than 5% impact overall. This would help in maintaining positive contribution even during worst cyclical depression.

Low Cost / Low gestation Investment

Varieties of investment opportunities and risk profile exist. In a typical case studied, some of the options available are given in table 4 (Details in the following chapter).

Table 4 - Supply to grid and Investment

Supply to Grid - MW	0.56	3.54	4.88	7.24	8.81	9.08
Investment* - Rs.Cr/MW	0.56	3.43	3.53	2.94	3.36	3.15

** Includes for Substation and Transmission*

Even the high cost (Low technical risk) option of Rs.3.5 Cr./MW compares favourably with normal thermal projects.

The project duration can range anything from 10 months to about 24 months depending upon the size and plant configuration. This is again about half the time required for thermal plants.

Further, many of the Central & State Government clearances required for thermal plants are not required in this case particularly for investment in an operating sugar plant.

Positive Environmental Impact

Co_2 emission in a fossil fuel based thermal plant is in the range of 1 Kg/KWH[4] depending on the carbon content in the fuel. Incremental bagasse consumption for surplus power could be estimated at around 20% of this figure. Thus, a Co_2 saving of 0.8 Kg/KWH is achievable. 4.5 Million MT of Co_2 emission could be avoided based on 2000 MW Co-generation power operating at a load factor of 80% for 150 days/year. This also offers an economic opportunity by trading on global Co_2 permit given supporting institutional arrangement.

Entec - N.Water Group (UK) - Environmental effects report supporting statement - August 1995

Risks

Risks can be broadly covered as under:

- Magnitude of Investment
- Risk to sugar manufacturing operations
- Other technical, commercial and financial risks.

Magnitude of Investment

Factors like present steam and power generation capacity and surplus, if any, steam pressure and temperature parameters, location of sub-station would effect the mangnitutde of investment. Very low cost opportunity was existing in one factory where just by installing a transmission line and sub-station surplus power of over 500 KW could be immediately supplied. On the other hand, an investment of Rs.25 Cr. could be made for generating surplus power of over 9 MW using high pressure and high efficiency technology.

Risk to sugar manufacturing operations

Maximum risk is involved when a topping cycle is used. Any disturbance in the topping T-G Set as a result of grid problem would interrupt manuracturing operation totally. Cost of such interruptions can be extremely high on account of production loss, machine failures, spillage of juice and sugar and quality degradation.

Similarly, in the event of low frequency (48 c/s is not uncommon) many of the critical pumps particularly operating for and under vacuum conditions can get deprimed.

The second stated problem can be faced even when a separate T-G Set is run in parallel with TG Set supplying power and steam to sugar factory.

Other Technical, Commercial and Financial Risks

Technical risks are involved in operating high pressure boilers and maintenance of instruments and control systems essential for operating high pressure system. Expertise for 42 Kg/CM^2 system has been developed to some extent though the importance of control of water purity is yet to be fully understood. Similarly boiler makers have to gain more experience in disigning, failsafe superheaters for high temperature sugar boilers.

Trained man-power for maintenance of instrument are also not available and manufacturer's support usually depends on the proximity of the factory to big cities.

Other financial and commercial risk particularly in respect of recovery of dues, availability of adequate fuels etc have been debated at length in many a forum and recently several initiatives have been taken by the State Governments in cooperation with MNES.

Development of Co-Generation Options

Considering the above factors and based on the study of the 3 factories visited, 7 different options have been conceptualised (Annexed Figure 1 to 8)[1]. These cover low pressure options under existing condition, high pressure options at 42 and 62 Kg/CM^2 both simple and topping cycle and parallel and stand alone operations and also offseasonal operations on condensing mode. The investment and risk profile of the various options denoted by 1 to 7 to correspond to figure 4 to 10 are given in Table 5.

Table 5 - Investment & risk profile of options

Risk \ Investment	Low	Medium	High
High		6 (Fig.7)	5 (Fig.6)
Medium	7 (Fig.8)	2 (Fig.3) 4 (Fig.5)	3 (Fig.4)
Low	1 (Fig.2)		4 (Fig.5)

Details of one particular case along with financial attractiveness of various proposals and marginal cost analyses are as given in annexed tables 6 and 7 respectively.[1] From this table it is clear that options are available for every type of risk profile for the particular factory. One can decide to take a small step to start with, go thru' the learning journey and decide which big step to take when. Most of the options are techno-economically feasible though relative attractiveness vary. A typical route could be as illustrated in Figure 9.

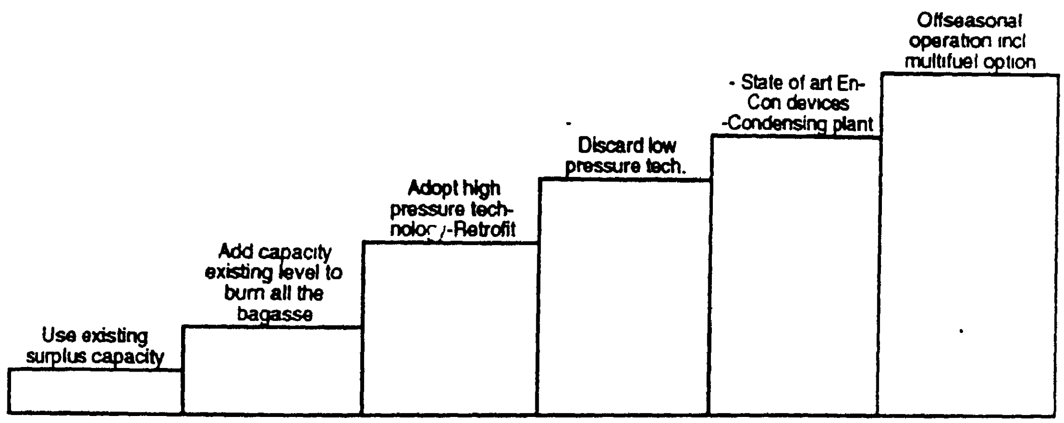


Figure 9 - Bagasse based Co-generation - a travel plan

Conclusions

The study reveals that there could be a co-generation solution to suit the need and capacity of every type of sugar operator. There is, therefore, a need for developing a marketing strategy by Financial institutions for identifying various market niches, local constraints and offer investment packages to suit the need and risk perception of every individual potential customer. It is also necessary to launch a continuous education programme for creating wide awareness of the multiple benefits to the society from bagasse cogeneration system. Feasibility of global trading in CO_2 permit could also be explored by the Institutions like MNES in Government and TERI outside.

All these steps would supplement the initiatives taken by MNES and IREDA in the last 2 years and would help in putting in place a rolling plan to achieve a target of minimum 2000 MW bagasse based co-generation power supply to the grid by the year 2000.

Annexed -5 pages of Tables (Page No. 8 to 12) and 4 pages of Figures (Pages No. 13 to 16).

Table 1 Bagasse Cogeneration Potential Estimate under High Efficiency Operating Conditions *

	Units	A.P.	Bihar	Gujarat	Haryana	Karnataka	Maharashtra	Punjab	T.N./Pond.	U.P.
A Cane Crushed	TCH	1,300	1,000	2,263	1,285	2,264	10,300	780	3,350	9,750
B Electricity Use	MW	39	30	68	39	68	309	23	101	293
C Steam Use	TPH	585	450	1,018	578	1,019	4,635	351	1,508	4,388
D BP Turbine Power Generated	MW	73	56	127	72	127	579	44	188	548
E Bagasse Content	% cane	32%	32%	34.5%	32%	32%	34%	32%	32%	33%
F Bagasse Production	TPH	416	320	781	411	724	3,502	250	1,072	3,218
G Steam Production	TPH	874	672	1,640	864	1,521	7,354	524	2,251	6,757
H Surplus Steam	TPH	289	222	621	285	503	2,719	173	744	2,369
Surplus Power Estimate										
I Condensing Turbine Power from Surplus Steam	MW	72	56	155	71	126	680	43	186	592
J Surplus BP Turbine Power	MW	34	26	59	34	59	270	20	88	256
K Surplus Power	MW	106	82	215	105	185	950	64	274	848
Total Surplus Power Estimate (approx.):				2800	MW					

* Table Approach	Units	Assumptions	Calculations
A Cane Crushed	TCH		Input
B Electricity Use	MW	30 KW/TCH	30/1000*(A)
C Steam Use	TPH	0.45 T steam/T cane	0.45 * (A)
D BP Turbine Power Generated	MW	8 TPH steam/MW	(C)/8
E Bagasse Content	% cane		Input
F Bagasse Production	TPH		(A) * (E)
G Steam Production	TPH	2.1 T steam/T bagasse	2.1 * (F)
H Surplus Steam	TPH		(G) - (C)
I Condensing Turbine Power from Surplus Steam	MW	4 TPH steam/MW	(H)/4
J Surplus BP Turbine Power	MW		(D)-(B)
K Surplus Power	MW		(I)+(J)

Table 2 Bagasse Cogeneration Potential Estimate under Low Efficiency Operating Conditions *

	Units	A P.	Bihar	Gujurat	Haryana	Karnataka	Maharashtra	Punjab	T N /Pond	U P
A Cane Crushed	TCH	1,300	1,000	2,263	1 285	2,264	10,300	780	3 350	9,750
B Electricity Use	MW	39	30	68	39	68	309	23	101	293
C Steam Use	TPH	715	550	1,245	707	1 245	5 665	429	1 843	5 363
D BP Turbine Power Generated	MW	72	55	124	71	124	567	43	184	536
E Bagasse Content	% cane	32%	32%	34.5%	32%	32%	34%	32%	32%	33%
F Bagasse Production	TPH	416	320	781	411	724	3 502	250	1 072	3 218
G Steam Production	TPH	803	618	1,507	794	1,398	6 759	482	2 069	6 210
H Surplus Steam	TPH	88	68	262	87	153	1 094	53	226	847
Surplus Power Estimate										
I Condensing Turbine Power from Surplus Steam	MW	19	14	56	18	33	233	11	48	180
J. Surplus BP Turbine Power	MW	33	25	57	32	57	258	20	84	244
K Surplus Power	MW	51	39	112	51	89	490	31	132	424
Total Surplus Power Estimate (approx.):				1400	MW					

* Table Approach	Units	Assumptions	Calculations
A Cane Crushed	TCH		Input
B Electricity Use	MW	30 KW/TCH	30/1000*(A)
C Steam Use	TPH	0.55 T steam/T cane	0.55 * (A)
D BP Turbine Power Generated	MW	10 TPH steam/MW	(C)/10
E. Bagasse Content	% cane		Input
F Bagasse Production	TPH		(A) * (E)
G. Steam Production	TPH	1.93 T steam/T bagasse	1.93 * (F)
H Surplus Steam	TPH		(G) - (C)
I Condensing Turbine Power from Surplus Steam	MW	4.7 TPH steam/MW	(H)/4.7
J Surplus BP Turbine Power	MW		(D)-(B)
K Surplus Power	MW		(I)+(J)

Table 6 Dhyaneswar S.S.S.K. (Maharashtra) - Options and Technical Results

Basecase : 48% LP + 5% HP
Crushing Rate 160 TCH

Boiler (2.) and turbine (3.) entries give the unit cost (lakh Rs) followed by the capacity.

OPTIONS.		0	1	2	2a	3	4	5	6	6a	7	7a	8	9	10	11	11a	12	12a
		Basecase (existing effic.)	S A 21	S A 21		Top 42	Top 42	S-A 42	S-A 42		S-A 42		Top 62	Top 62	S A 62	S A 62		S A 62	
1 Option Parameters			case 2	case 4	case 4a	case 2	case 3	case 2	case 4	case 4a	case 5	case 5a	case 2	case 3	case 2	case 4	case 4a	case 5	case 5a
Boiler Pressure (bar)		21	21	21	off-	42	42	42	42	off-	42	off-	62	62	62	62	off-	62	off-
New Turbine Types				EC	season	BP	BP & SC	BP	BP & EC	season	BP & SC	season	BP	BP & SC	BP	BP & EC	season	BP & SC	season
KW surplus		0	558	3 957	3 600	3 641	3 544	2 261	7 237	6 750	7 237	2 250	4 878	4 878	3 476	9 051	8 550	9 051	4 550
Text Figure No		1				6	7	2	4		5		6	7	2	4		5	
2. New Boiler Capacity (TPH)				UnitCost lakhRs		UnitCost lakhRs	UnitCost lakhRs	UnitCost lakhRs	UnitCost lakhRs		UnitCost lakhRs		UnitCost lakhRs	UnitCost lakhRs	UnitCost lakhRs	UnitCost lakhRs		UnitCost lakhRs	
21 310 existing		90		5 / 15															
42 430						8.5 / 85	8.5 / 85	8.5 / 85	8.5 / 105		8.5 / 105								
62 450													12 / 85	12 / 85	12 / 85	12 / 105		12 / 105	
Min fuel premium					0%		0%			0%		0%		0%			0%	2%	0%
3 New Turbine Capacity (KW)																			
BP 21/1 existing		4000																	
BP 42/21 (1)						35 / 4000	35 / 4000												
BP 62/21 (1)													45 / 5000	45 / 5000					
BP 42/1								40 / 5500	40 / 3500		35 / 12000								
BP 62/1															45 / 12000	45 / 3500		50 / 7000	
SC 42							80 / 4000				85 / 2500	2500							
SC 62														75 / 5500				80 / 5500	5500
EC 21/1/C				80 / 4000	4000														
EC 42/1/C									70 / 7500	7500									
EC 62/1/C																75 / 9500	9500		
4 Grid Connection																			
Substation (KW) C	0.012 lakhRs/KW		1000	4000		4000	4000	2500	7500	1	7500		5000	5000	3500	9500		9500	
Trans. Line (km)			4	4		4	4	4	4		4		4	4	4	4		4	
5 Fuel Use (tons)																			
In season	160 d surplus 39 560 tons																		
Bagasse (tons)	350	167 030	168 400	206 590		160 310	160 310	159 910	206 520		206 520		162 120	162 120	163 340	206 600		206 670	
beyond Basecase			1 370	39 560		(8 720)	(6 720)	(7 120)	39 490		39 490		(4 910)	(4 910)	(3 690)	39 570		39 570	
Steam/bagasse ratio (T/T)		1.90	1.90	1.90		1.93	1.93	1.93	1.93		1.93		1.92	1.92	1.92	1.92		1.92	
Off Season	165 days with 10% in plant use																		
Bagasse (tons)																			
in house	350 Rs/ton				0		36 146			0		0		44 410			0		0
Purchased	430 Rs/ton				43 488		0			68 845		22 948		796			79 341		45 934
GWH Sold					13.54		13.33			25.39		8.46		18.35			32.17		18.62
Efficiency of gross generation (on GCV)					14%		18%			16%		16%		18%			18%		18%
kg bagasse/kwh	2300 kcal/kg (GCV)				2.89		2.44			2.44		2.44		2.22			2.22		2.22
Coal	1575 Rs/ton				0		(0)			0		0		0			0		0
GWH Sold					0.00		0.00			0.00		0.00		0.00			0.00		0.00
Efficiency of gross generation (on LHV)				15%	18%		18%			18%		18%		20%			20%		20%
kg coal/kwh	4500 kcal/kg (LHV)			1.27	1.06		1.06			1.06		1.06		0.96			0.56		0.56
6 Electricity Sold (GWH)			1.93	13.81	27.38	12.26	25.58	7.81	25.01	50.40	25.01	33.48	16.86	35.21	12.01	31.31	63.48	31.31	49.94
In Season	160 d at PLF 90%		1.93	13.81	13.81	12.25	12.25	7.81	25.01	25.01	25.01	25.01	16.86	16.86	12.01	31.31	31.31	31.31	31.31
Off Season	165 d at PLF 95%				13.54		13.33			25.38	0	8.46		18.35			32.17		18.62

09 Dec

Nomenclatures: SA - Simple cycle LP - Low pressure TCH - Ton cane crush/hr. Top - Topping cycle BP - Back pressure EC - Extraction condensing SC - Straight condensing
TPH - Tonnes/Hr C - Condensing GCV - Gross calorific value LHV - Lower heating value PLF - Plant load factor d - Days

Table 7 Dhyaneswar S.S.S.K. (Maharashtra)

	Basecase	S A 21	S-A 21 EC	off-season	Top 42 BP	Top 42 BP & SC	S A 42 BP	S-A 42 BP&EC	off-season	S A 42 BP & SC	off-season	Top 62 BP	Top 62 BP&SC	S A 62 BP	S A 62 BP&EC	off-season	S-A 62 BP&SC	off-season
Case		case 2	case 4	case 4a	case 2	case 3	case 2	case 4	case 4a	case 5	case 5a	case 2	case 3	case 2	case 4	case 4a	case 5	case 5a
New Turbine Types	21	21	21		42	42	42	42		42		62	62	62	62		62	
Boiler Pressure (bar)																		
Figure Number	1				6	7	2	4		5		6	7	2	4		5	
Option No.:	0	1	2	2a	3	4 (off-season)	5	6	6a	7	7a	8	9 (off-season)	10	11	11a	12	12a
1 Total Investment Cost (million Rs)																		
Boiler		0	8	8	72	72	72	89	89	89	89	102	102	102	126	126	126	126
Turbines		0	32	32	14	48	22	67	67	63	63	23	64	32	87	87	79	79
Interconnection (in plant) 5%		0	2	2	4	6	5	8	8	8	8	6	8	7	11	11	10	10
Civil & Proj. Mgmt 10%		0	4	4	8	12	10	16	18	16	16	13	17	14	22	22	22	22
Grid Connection		3	8	8	8	8	6	13	13	13	13	10	10	7	16	16	16	16
Total Capital	0	3	54	54	106	145	114	193	193	190	190	153	201	161	262	262	253	253
million US$		$0.1	$1.7	$1.7	$3.4	$4.7	$3.7	$6.2	$6.2	$6.1	$6.1	$4.9	$6.5	$5.2	$8.5	$8.5	$8.2	$8.2

2 Operating Parameters

	No days	PF
Season	160	90%
Off Season	165	95%

(aux. in-plant power use 10%)

	Basecase	S A 21	S-A 21 EC	off-season	Top 42 BP	Top 42 BP & SC	S A 42 BP	S-A 42 BP&EC	off-season	S A 42 BP & SC	off-season	Top 62 BP	Top 62 BP&SC	S A 62 BP	S A 62 BP&EC	off-season	S-A 62 BP&SC	off-season
3. KW surplus		558	3,997	3,799	3,844	3,644	2,261	7,237	6,994	7,237	4,744	4,878	4,878	3,478	9,061	8,806	9,061	7,008
US$/KW		$160	$430	$480	$980	$1,320	$1,630	$860	$890	$840	$1,290	$1,010	$1,330	$1,500	$930	$960	$900	$1,170
4. Electricity Sold (GWH)	–	1.93	13.81	27.38	18.28	25.58	7.81	25.01	50.40	25.01	33.48	16.66	35.21	12.01	31.31	63.48	31.31	49.94
Off Season Sales				13.64		13.33			25.39		8.46		18.35			32.17		18.62
5 Annualized Costs (million Rs.)																		
Capital 20%	0.0	0.6	10.7	10.7	21.6	28.9	22.9	38.7	38.7	37.9	37.9	30.7	40.2	32.3	52.5	52.5	50.6	50.6
Non Fuel O&M 2%	0.0	0.1	1.1	1.1	2.2	2.9	2.3	3.9	3.9	3.8	3.8	3.1	4.0	3.2	5.2	5.2	5.1	5.1
Fuel in Season 350	..	0.5	13.8	13.8	-2.4	-2.4	-2.6	13.8	13.8	13.8	13.8	-1.7	-1.7	1.3	13.8	13.8	13.8	13.8
Fuel (off season)	0.0	0.0	0.0	18.7	0.0	12.7	0.0	0.0	29.8	0.0	9.9	0.0	15.9	0.0	0.0	34.1	0.0	19.8
Totals	0.0	1.1	25.6	44.3	21.3	42.1	22.7	56.3	85.9	55.5	65.4	32.0	58.4	34.2	71.6	105.7	69.5	89.3
6 Unit KWH Costs (Rs/kwh)																		
Capital		0.29	0.78	0.39	1.78	1.13	2.93	1.55	0.77	1.52	1.13	1.82	1.14	2.69	1.68	0.83	1.62	1.01
Non Fuel O&M		0.03	0.08	0.04	0.18	0.11	0.29	0.15	0.08	0.15	0.11	0.18	0.11	0.27	0.17	0.08	0.16	0.10
Fuel		0.25	1.00	1.19	0.19	0.40	0.32	0.55	0.86	0.55	0.71	0.10	0.40	0.11	0.44	0.76	0.44	0.67
Totals (Rs/kwh)		0.57	1.86	1.62	1.74	1.65	2.90	2.25	1.71	2.22	1.96	1.90	1.66	2.85	2.29	1.68	2.22	1.79
7 Unit Fuel Costs (Rs/kwh)																		
In Season		0.25	1.00	1.00	0.19	-0.09	0.32	0.55	0.55	0.55	0.55	0.10	0.05	-0.11	0.44	0.22	0.44	0.28
Off Season				1.38		0.95			1.17		1.17		0.87			1.06		1.06
Fuel Purchases Required				Yes					Yes		Yes					Yes		Yes

8 MARGINAL COST ANALYSIS

Option No.:	0	1	2 S A 21	2a	3 Top 42	4 Top 42	5 S-A 42	6 S-A 42	6a	7 S-A 42	7a	8 Top 62	9 Top 62	10 S-A 62	11 S-A 62	11a	12 S-A 62	12a
8a		0->1a	1->2	2->2a	2->3	3->4	4->5	5->6	6->6a	4->7	7->7a	3->8	6a->9	9->10	10->11	11->11a	11->12	12->12a
Incremental Annual Costs (million Rs)		1.1	24.5	18.7	-4.3	20.8	-19.4	33.7	29.8	13.4	9.9	10.7	-27.5	-24.2	37.4	34.1	-2.0	19.6
Incremental GWH sold		1.93	11.89	13.54	-1.87	13.33	-17.77	17.20	25.39	-0.57	8.46	4.6	-15.20	-23.20	19.30	32.17	0.00	18.62
Incremental Rs/kwh Cost		0.57	2.07	1.38	-2.76	1.56	-1.09	1.96	1.17	-23.54	1.17	2.32	-1.81	-1.04	1.94	1.06	n.a.	1.06
b.				1->2a	1->3	2->4	3->5	3->6	4->6a	3->7	4->7a	5->8	4->9	8->10	6->11	6a->11a	8->12	11a->12a
Incremental Annual Costs (million Rs)				43.2	20.2	16.5	1.3	35.0	43.8	34.2	23.3	9.4	16.3	2.2	15.2	19.7	37.5	-18.4
Incremental GWH sold				25.43	10.32	11.77	-4.43	12.76	24.82	12.76	7.89	9.04	9.63	-4.85	6.30	13.08	14.46	-13.54
Incremental Rs/kwh Cost				1.70	1.96	1.40	-0.30	2.74	1.77	2.68	2.95	1.03	1.69	-0.45	2.42	1.51	2.59	-1.21
8c.						2a->4	1->5	2a->6	2a->6a		6a->7a		2a->9		8->11	9->11a	7->12	7a->12a
Incremental Annual Costs (million Rs)						-2.2	21.6	12.0	41.6		-20.6		14.1		39.5	47.3	14.0	23.9
Incremental GWH sold						-1.8	5.9	-2.3	23.0		-16.9		7.9		14.5	28.3	6.3	16.5
Incremental Rs/kwh Cost						-1.26	3.67	5.11	1.81		-1.21		1.79		2.74	1.67	2.72	1.45

09 Dec

Table 8 - Estimation of Co-generation potential

Total cane crush	8,75,000 + 7,00,000 T = 15,75,000 T/Yr.	
Bagasse as % age of cane	35	
Bagasse production	5,51,250 T/Yr	
Steam potential @ 2 times begasse	11,02,500 T/yr	
Steam requirement @ 50% cane crush	7,87,500 T/Yr	
Surplus steam to be put in - condensing turbine.	3,15,00 T/Yr	
For power calculation, following.assumptions are made:		
Boiler steam conditions	42 bar 430 degree C.	
Exhaust condition	1 bar.	
Power requirement for factory operation	35 KWH/T cane.	
Steam consumption in BP Turbine	8 Kg/KWH	
Steam consumption in condensing turbine	4.3 Kg/KWH	
Calculation:		
Cane crushed	15,75,000 T	a
Steam required @ 50% of 'a'	7,87, 500 T	b
Power produced (From BP turbine) @ 8 Kg/KWH ('b'/8)	9,84,37,500 KWH	c
Power required @ 35 KWH/TC ('a' X 35)	5,51,25,000 KWH	d
Surplus from BP turbine (c - d)	4,33,12,500 KWH	e
Steam flow in condensing turbine	3,15,000 T	f
Power produced @ 4.3 Kg/KWH ('f'/4.3)	7,32,55,800	g
Overall surplus (e+g)	11,65,68,300 KWH.	

Table 9 - Details of costs & Contribution

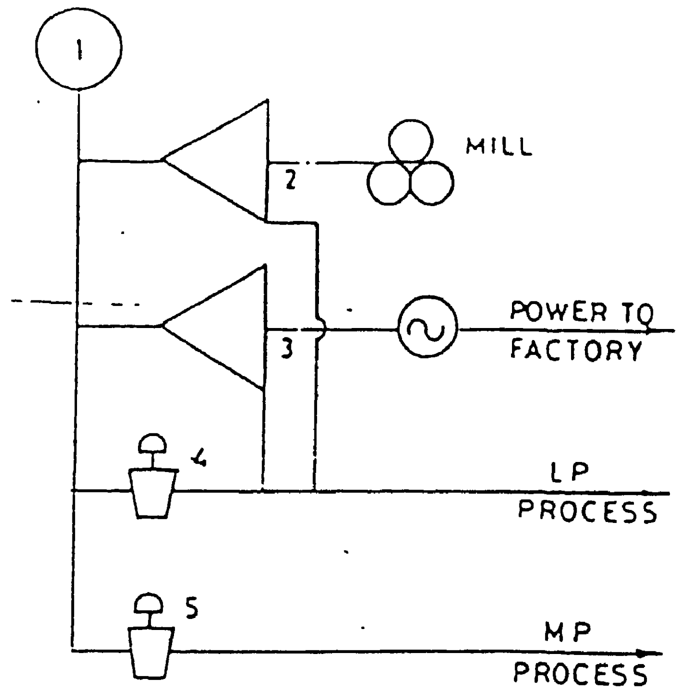
Sugar:		Target	Present*	Impact
Cost of production	- Cane	6680	7820	
(Average)	- Stores	400	400	
(Rs./T of sugar)	- Elec. & Fuel	-	50	
	- Labour	310	2625	
	- Packaging	220	220	
	- Others	500	1000	
		8110	12115	4005
Realisation	- FS - (@ 60% of 12000)	7200	7080	
(Rs/T of sugar)	- Levy			
	(40% of 7600)	3040	3040	
	- Total	10240	10120	120
Contribution	- Rs/T	2130	(-) 1995	4125
	- Rs. Cr/Yr	29 50	(-) 2 70	32 20
Molasses:				
Molasses production @ 4 5 cane crush	-T/Yr	70875	10485	
Sales realisation	- Rs /T	1000	1000	
Annual Contribution	- Rs Cr/Yr	7 00	1 05	5 95
Power:				
Power sold	- Cr. KWH/Yr	11 66		
Realisation	- Rs/KWH	2 00		
Annual contribution	- Rs.Cr/Yr	23 00	-	23 00
Total annual contribution	- Rs. Cr/Yr	59 50	(-)1 65	61 15

* Based on estimated present cost at Launya & averaging of labor cost.

Figure 1 Present Systems

LEGENDS

1 BOILER (S)
2 MILL TURBINE/MILLS
3 POWER TURBINE(S)/ GENERATOR (S)
4 PRESSURE REDUCING VALVE (PRV) FOR LOW PRESSURE(LP) PROCESS STEAM.
5 PRV FOR MEDIUM PRESSURE (MP) PROCESS STEAM



LEGENDS

1. BOILER(S)
2. MILL TURBINE/MILLS
3 POWER TURBINE(S)/GENERATOR(S)
4 PRESSURE REDUCING VALVE (PRV) PROCESS STEAM-LOW PRESSURE
5 PRV FOR MEDIUM PRESSURE (MP) PROCESS STEAM
6 NEW BP SET TO ELIMINATE LP PRV

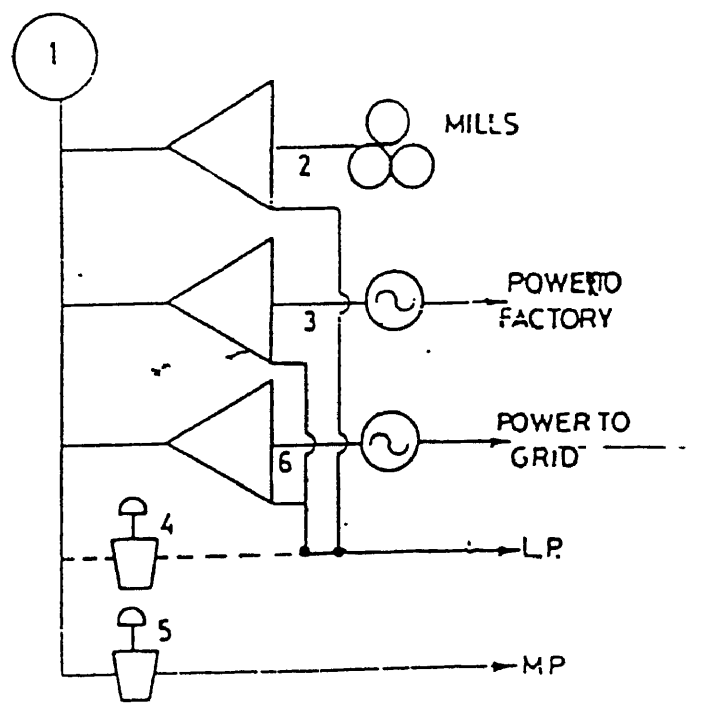
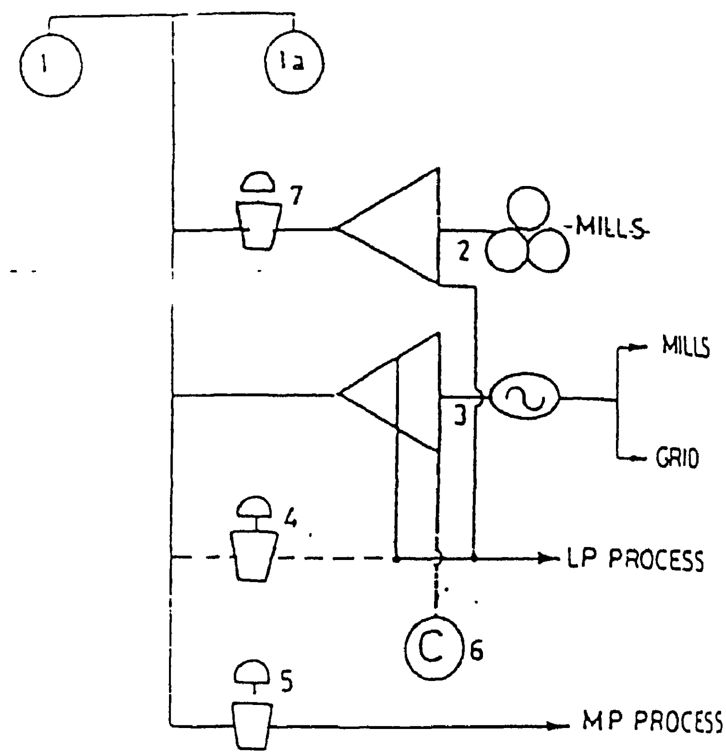


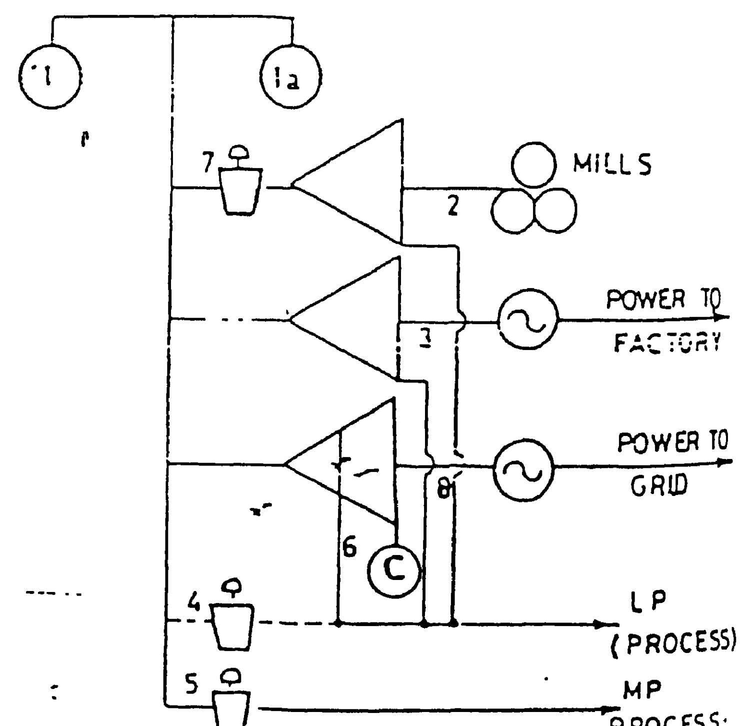
Figure 2
- New Back-Pressure (BP) Turbine Set to Minimize/Eliminate Pressure Reducing Valve Use

Figure 3
New Extraction Condensing Turbine and
Boiler Capacity to Burn All Bagasse In-Season

LEGENDS
1 BOILERS (S)
1a ADDITIONAL BOILER
2 MILL TURBINE(S)/MILLS
3 POWER TURBINE(S)/GENERATORS EXTRACTION CONDENSING
4 PRESSURE REDUCING VALVE (PRV) FOR PRESSURE (LP) PROCESS STEAM (STANDBY)
5 PRV FOR MEDIUM PRESSURE (MP) PROCESS STEAM
6 CONDENSER
7 PRV FOR EXISTING LP MILL TURBINE (IF NEW H.P MILL TURBINE NOT INSTALLED)



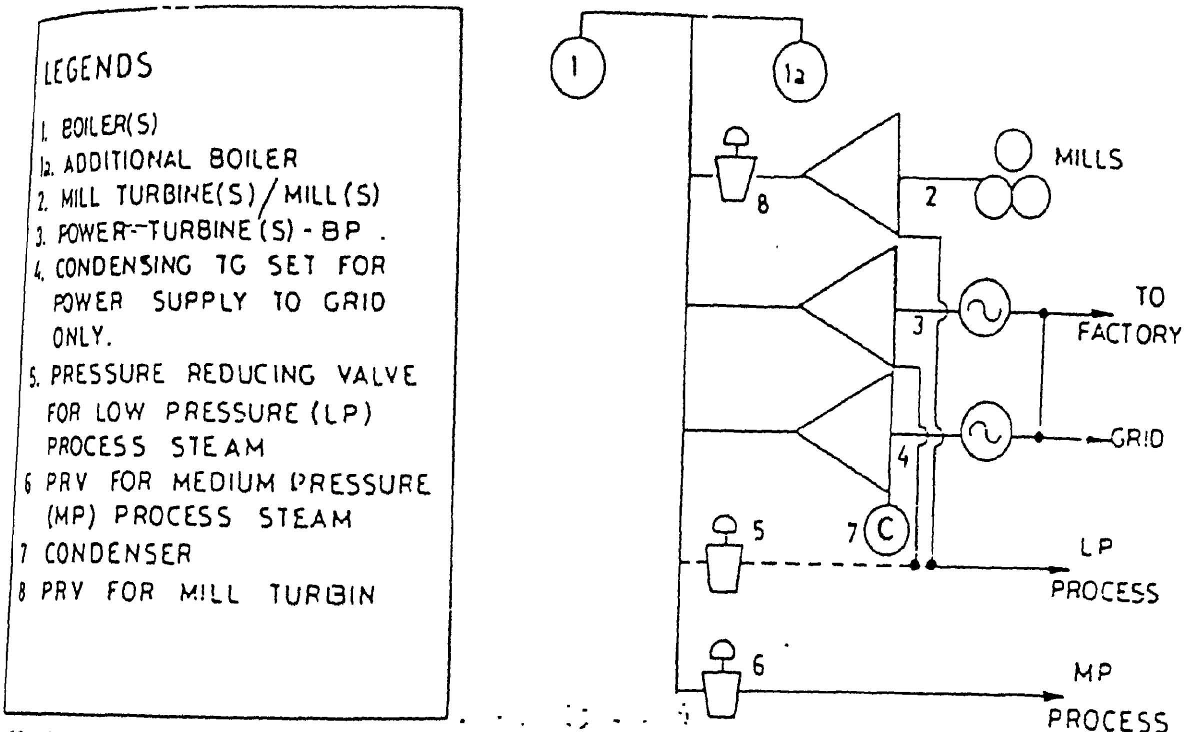
LEGENDS
1 BOILER (S)
1a ADDITIONAL BOILER
2 MILL TURBINE(S)/MILLS
3 BACK PRESSURE POWER TURBINE(S)/GENERATORS
4 PRESSURE REDUCING VALVE (PRV) FOR LOW PRESSURE (LP) PROCESS STEAM
5 PRV FOR MEDIUM PRESSURE (MP) PROCESS STEAM
6 CONDENSER
7 PRV FOR EXISTING MILL TURINES
8 SEPARATE EXTRACTION CONDENSING TG SET FOR POWER SUPPLY TO GRID ONLY



- PRV FOR LP NORMALLY NOT IN CIRCUIT STEAM MAKE UP FROM EC SET.
- BOILER FOR ADDITIONAL CAPACITY.
- EC SET FOR GRID.
- LP STEAM OPERATING IN PARALLEL

Figure 4
New Back-Pressure and Extraction Condensing Turbines and
Boiler Capacity to Burn All Bagasse in Season
and Off-Season Surplus Generation from Condensing Turbine

Figure 5
- New Back-Pressure & Straight Condensing Turbines and Boiler Capacity to Burn All Bagasse in Season and Off-Season Surplus Generation from Condensing Turbine



- PRV FOR LP NORMALLY NOT IN CIRCUIT
- BACK PRESSURE SET SIZED FOR NO FLOW THROUGH PRV FOR LP
- BOILER FOR ADDITIONAL CAPACITY.
- CONDENSING TG SET FOR GRID.
- POWER IN PARALLEL
- CONDENSING SET STAND ALONE CAN BE RUN IN OFF SEASON.

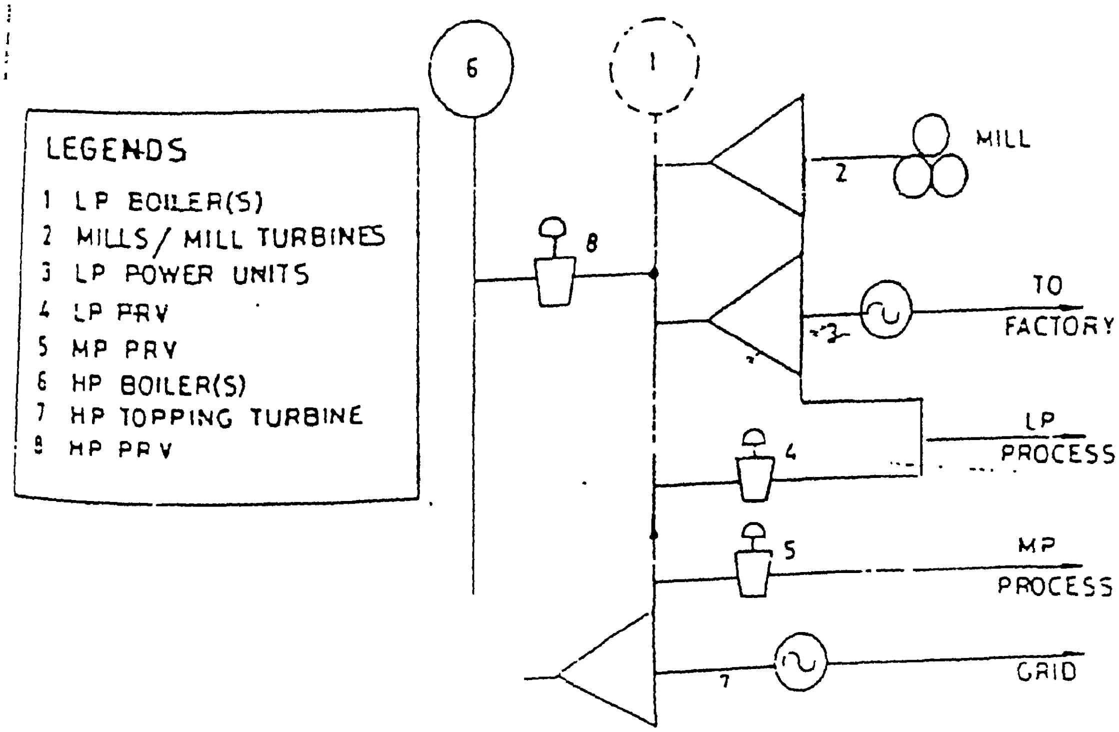
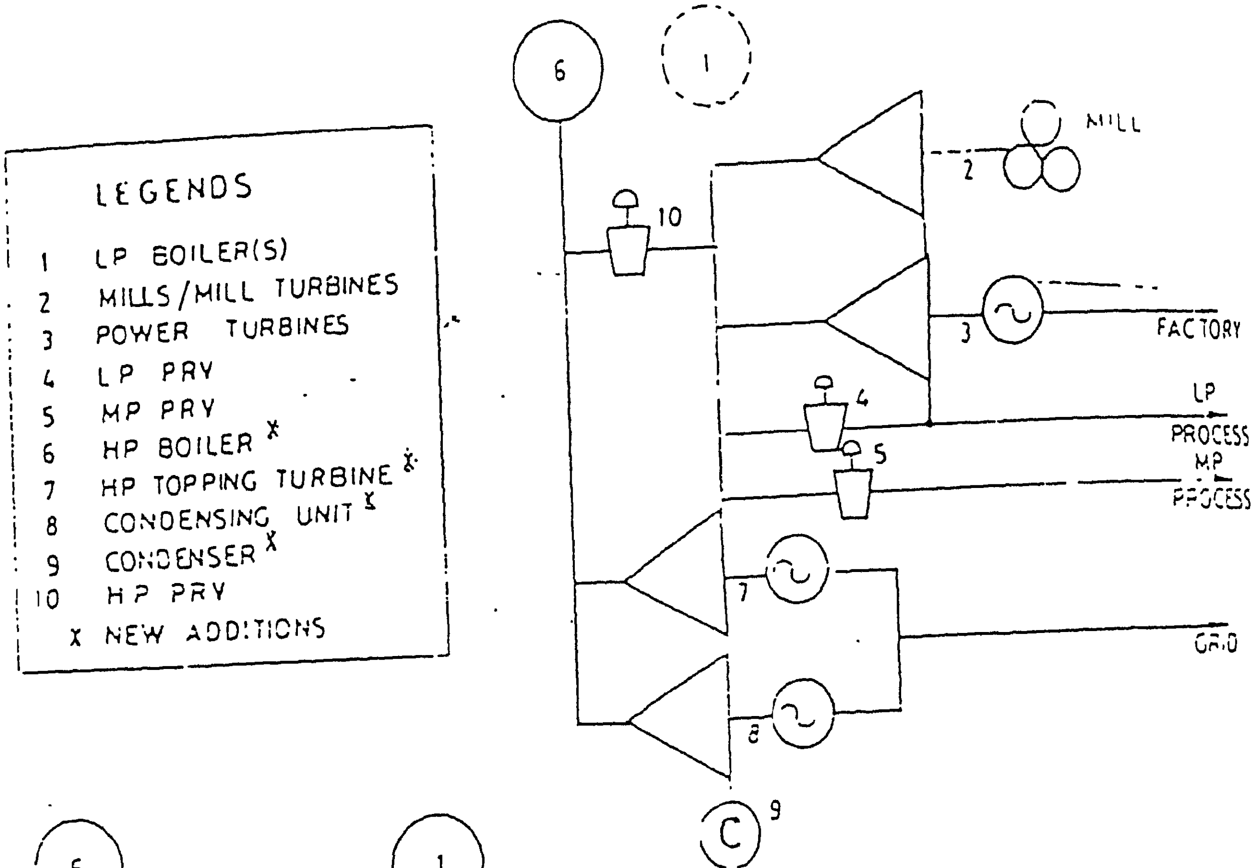


Figure 6
Back Pressure Topping System (Case 2 of TOPPING Model)

Figure 7
Back Pressure Topping System for In-Season Operations and Straight Condensing Turbine for Off-Season Operations (Case 3 of TOPPING Model)



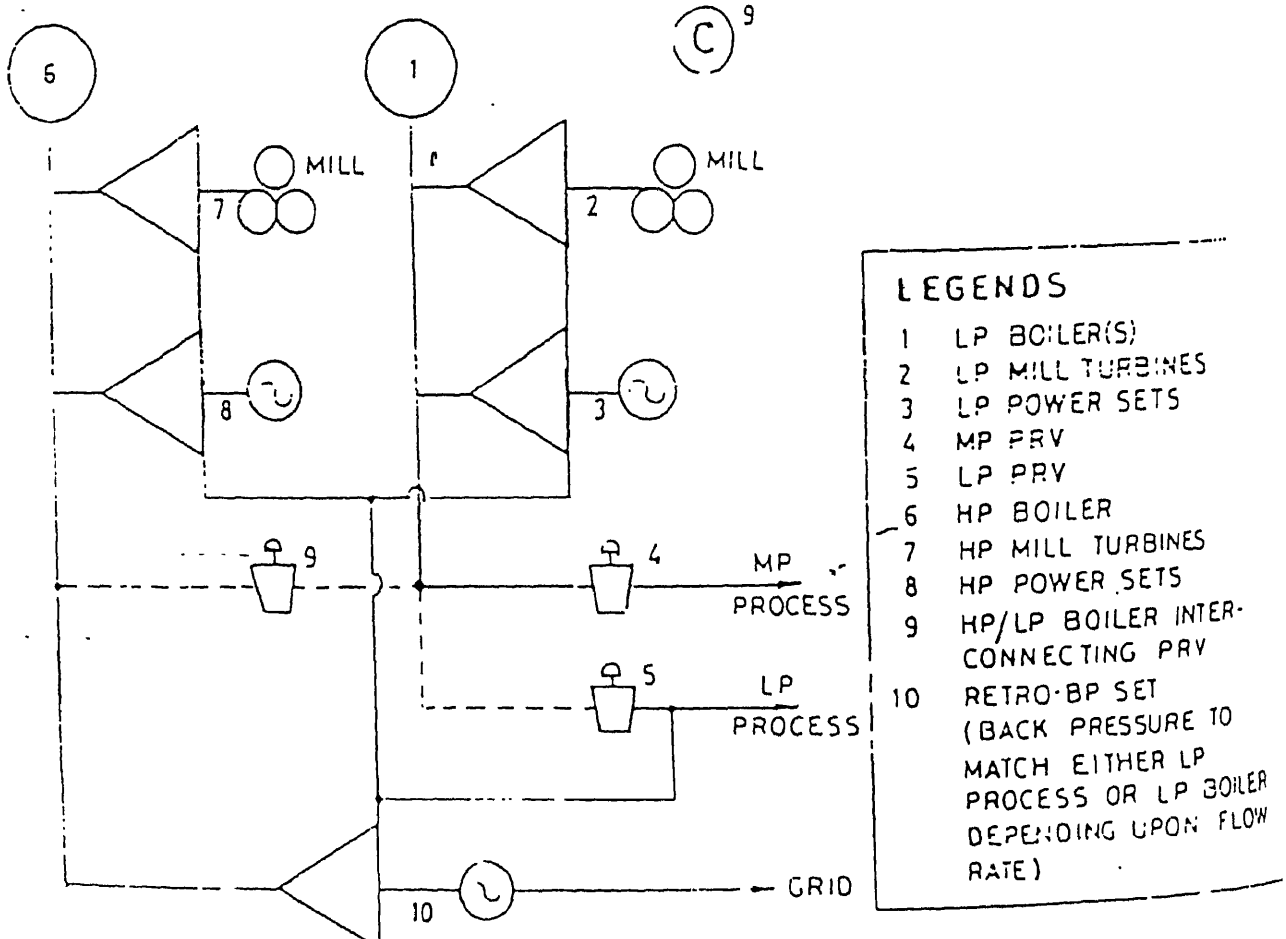


Figure 8
Retrofit for Dual Pressure Operating Plants

BIOMASS ENERGY SYSTEM

MS SANGEETA WIJ
USAID

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

BIOMASS ENERGY SYSTEM

At Hotel Taj Palace, New Delhi - March 10-12, 1996

- **Ms. Sangeeta Wij**
Program Manager (GEP)
USAID/New Delhi

Background

India's burgeoning population,massive poverty and accelerating industrial growth are all contributing factors to a high level of environmental pollution.This pollution is a present threat to national health and safety, a contributor to global environmental problems particularly through rising greenhouse gas emissions (GHGs), and a long-term threat to the sustainability of Indian development.

The overall economic growth rate in India is now of the order of five percent and accelerating as the effects of major economic reform and liberalization take hold.Such growth can have severely negative consequences for the environment unless policies and technologies are in place to limit environmental damage.Use of agricultural wastes for domestic energy needs,the inefficient burning of low-grade coal and other fossil fuels in commercial energy production, and the proliferation of motorized transport are all major contributors to an increasing volume of air pollution, much of it the type associated with global warming.The pressure for the conversion of more land to agricultural and industrial use and the lack of proper disposal of increasing volumes of solid and hazardous wastes endanger the diversity of India's plant and animal life and reduce the forest cover critical to the absorption of carbon dioxide, the key greenhouse gas.

The United States Agency for International Development (USAID) as a worldwide organization has recognized the significance of reducing greenhouse gas emissions and global environment is now one of its four key areas of focus. Considering the overall development constraints in India and requirements of the Global Environment Facility (GEF) , USAID/India has taken up a project to help in mitigation of increases in GHGs associated with global warming.

Introduction

The Greenhouse Gas Pollution Prevention (GEP) Project is a seven year $19 million effort designed to activate changes in volume of GHG productions in India.However the project is primarily a demonstration effort combining the strengths of Indian industry with the technical prowess of United States's Department of Energy's Pittsburgh Energy Technology Center (PETC) of U.S. Department of Energy (USDOE) to bring clean long term solutions to India's energy challenges with IDBI and NTPC as Indian counterparts. GEP promotes bagasse and biomass cogeneration as well as advanced coal conversion technologies in fossil fuel based power plants.Under the Alternate bagasse cogeneration (ABC) component, cogeneration (production of steam and electricity) in

sugar mills using bagasse and other biomass fuels in high efficiency boilers is being supported through partial funding of demonstration plants. Experts feel that as much as 5000 MW of electricity can be generated through efficient combustion of bagasse/biomass fuels in Indian sugar mills.

GEP project will directly contribute towards reducing emissions of Carbon dioxide in India by 6 to 10 millions tons per year. The demonstration effects of the project are expected to be even more far-reaching, leading to reductions of 100 million tons or more of Carbon dioxide per year from potential annual emissions levels.

Bagasse cogeneration represents one of the most exciting areas of energy development in India today.Until recently most sugar mill boilers were designed primarily to meet the electricity needs of the mill during the crushing season and to incinerate sugarcane waste instead of maximising energy production.However, the increasing willingness of State Electricity Boards to pay remunerative tariffs for electricity sold to the grid makes increasing the efficiency of cogeneration operations an attractive proposition for the sugar mills.

The ABC Component

This component builds on prior USAID and UNDP financed studies which proved the potential for sugar cogeneration in India and for similar DOE projects in India. India's Ministry of Nonconventional Energy Sources has instituted a comprehensive National Bagasse Cogeneration Program providing a package of financial incentives to sugar cogeneration project developers to use advanced technology.A technical and management seminar sponsored by USAID in February, 1995 contributed to awareness of the fundamentals of bagasse cogeneration within the industry. Recently, Department of Science and Technology has come up with an excellent scheme of soft loans upto 60% of the project cost to the sugar industry for upgrading and modernising existing technology at a concessional rate of 6 % interest.

Under the ABC component of GEP project, a Matching Grants Program has been drawn up describing in detail the different categories of grant , the eligibility conditions and the grant applications. This program had been circulated to all the sugar industries in India crushing more than 2500 tons per day and three workshops were organised in December 95 to discuss this program with the sugar industry personnel along with representatives of State Electricity Boards and MNES. These workshops were fairly well-attended with a good response to the subject of cogeneration and the related policy issues, PPA, Banking and Wheeling etc. The last date of receiving the applications for assistance is end of February after which the screening process will be taken up jointly by USAID and IDBI The projects are likely to be selected before end of April 96 The salient features of the ABC grant are highlighted for your information :

Eligibility

- More than 2500 TCD
- Operating on Bagasse/biomass for more than 270 days in a year
- Operating at a minimum of 60 kg/sq.cm. pressure and 430 deg temp. boilers

Details of Grant

- A cost shared Matching Grant of $25,000 maximum for developmental work related to storage and handling of biomass in Indian context. About Twelve such studies are likely to be funded.
- A cost shared Technical Assistance of $25,000 maximum for preparation of DPR for a new Cogeneration Plant or Modernisation of existing facilities.
- Financial Assistance of 10 % of the project cost subject to a maximum of $ 1.7 million each. About five such demonstration projects are likely to be supported.

COGENERATED POWER REGULATIONS AND TARIFFS IN FRANCE

MR J P TABET
ENVIRONMENT AND ENERGY MANAGEMENT AGENCY

Cogen INDIA '96
THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

COGEN INDIA'96
New Delhi, March 11&12, 1996

Cogenerated power regulations and tariffs in France

J.P. TABET
Environment and Energy Management Agency
Ademe, FRANCE

Ademe

The electric system in France

- **A vertically integrated state owned utility**

  Electricité de France (EdF)

  - *Power generation: 444 TWh (in 1995)*

    79% nuclear *15% hydro* *6% coal & heavy fuel oil*

  - *Power exportation: 73 TWh (16%)*

- **Independant producers**
  - *Power generation: 27 TWh*

    25% hydro *30% coal mines* *45% self generation*

  - *Single buyer sale to EdF or self consumption*

- **Transport and import/export : EdF monopoly**
- **Distribution: conceded by municipalities to:**
  - *EdF: 96%* *Local utilities: 4%*

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Cogeneration in France

- **Power capacity: 2 200 MW**
  - *Mainly: backpressure steam turbines in industry*
- **Power generation: 5 000 GWh** (1. 4% of national consumption)
- **Rates of growth (installed power capacities)**

1975-1980:	*weak or negative*	*(fuels prices and nuclear program)*
1991 - 1993	*+ 50 MW per year*	
1994	*+ 100 MW*	
1995	*+ 140 MW*	

(European Union: + 2 000 MW in 1994)

- **Characteristics of recent growth**

Mainly gas turbines and engines	*(electric output and tax motives)*
Based on thermal requirements	*(regulations motives)*
Importance of commercial sector	*(50% until 1994)*

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Independant producers status in France

- **From 1946 (Electricity Nationalization Law)**
  - *Free private generation for self consumption*
  - *No possible sales to other consumers*
  - *Obligation of purchase by the grid (EdF) under a 8 MW limitation*
  - *Tarriffs of purchase indexed to tarriffs of sale (avoided costs formula)*
- **From 1980**
  - *The 8 MW limit is supressed for power generation from District Heating plants*
- **From 1995**
  - *Obligation of purchase restricted to electricity generated by:*
    - ✓ *Cogeneration (certificate of agreement is needed)*
    - ✓ *Renewable Energy Sources (wind, solar, hydro, biomass)*
    - ✓ *Municipal and industrial wastes*
    - ✓ *District Heating plants*

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Cogeneration certificate of agreement

- **From 1995, in order to:**
  - *Sell power to the grid*
  - *Gain from tax incentives*

- **Conditions are:**
  - *Global output above 65% (electric + thermal)*
  - *Heat on power ratio above .5*
  - *Heat production is defined as internally valorised or sold in normal economic conditions*

- **Certificate is:**
  - *issued by local offices of Ministry of Industry and Energy*
  - *subject to inspections by the same*
  - *not needed for previous firmed purchase contracts*

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Public incentives for cogeneration

- These incentives were decided in 1991 and 1992
- Fiscal policy
  - *Exemption on fuel taxes:*
    - *Gas: - 8% in average*
    - *Low-sulphur heavy fuel-oil: - 15% in average*
  - *Accelerated amortization (one year fiscal mortgage)*
  - *Exemption of 50% of the professional tax*
- Subsidies
  - *50% grant for engineering feasibility study (managed by ADEME)*
  - *10-30% grant on environmental overcosts (managed by the Air Tax Fund)*
- Tarrifs
  - *Until now: on a generation and transmission avoided costs basis*
  - *1996 project: summer incentive tarrifs + environmental bonus*

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Power purchase tarriffs by the grid

- **Without guaranteed power capacity**

  ⇨ *Hydro, wind turbines, ...*

  - ❑ *Single part tarriff, remuneration only for generated kWh's*
  - ❑ *Two or four seasonal periods, regularity bonus of 20% in winter*
  - ❑ *Average global remuneration in 1994: $ 6.4 for 100 kWh (Hydro)*
    $ 5.8 for 100 kWh (Wind turbines)

- **With guaranteed power capacity**

  ⇨ *Cogeneration, municipal waste plants, ...*

  - ❑ *Double part tarriff, remuneration for guaranteed kW's and generated kWh's*
  - ❑ *Calculated from sales tarriffs (Very Long Use option)*
    - ✓ *Abatement from -9% to -17% for guaranteed power part*
    - ✓ *Abatement from -4% to -6% for generation part*
    - ✓ *Generation part strongly dependant on hour & season period*
  - ❑ *High penalities in case of power failure: up to $ 1.1 per kWh*

Power sales tarriffs in France

- **Based on four principles**
  - *Long Term Marginal Cost for the structure of tarriffs*
  - *Utility financial equilibrium for the level of tarriffs*
  - *Geographical levelling of tarriffs (equity between regions)*
  - *Two-parts tarriff: power capacity needs and power generation needs*
- **Public tarrifs**
  - *fixed by a governmental decree (normally once a year, in february)*
  - *applicable by EdF and other utilities, allover the country (overseas included)*
  - *no commercial reductions or bargains*
  - *State-EdF planning contract: average prices are decreasing by 1.25% each year (in constant money)*
- **Three families of tarriffs**
  - *Domestic uses: from 3 to 36 kVA, simple or night&day tarriff*
  - *Commercial uses: from 36 kVA to 250 kVA, with 4 hour&season periods*
  - *Industrial uses: above 250 kW, with 4, 5 or 8 hour&season periods*

Industrial power sales tarriffs (1)

- **3 classes**
  - *"A" tarriffs: between 250 kW and 10 MW*
  - *"B" tarriffs: between 10 MW and 40 MW*
  - *"C" tarriffs: above 40 MW*
- **4 versions**
  - *Very Long Use : kW is more expensive, kWh is less expensive*
  - *Long Use*
  - *Average Use*
  - *Short Use : kW is less expensive, kWh is more expensive*
- **4 types of hour & season divisions**
  - *"5 periods" : Peak, full and empty winter, full and empty summer hours*
  - *"8 periods" : same, plus full and empty mid-season and July-August hours*
  - *"modulate" : 4 "real time" periods : peak, winter, mid-season,summer*
  - *"EJP": 1 "real time" peak period + 3 fixed seasonal periods*

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Industrial power sales tarriffs (2)

- **Number of hours for each period**
  - *Peak: between 249 and 396 hours*
  - *Winter: between 1170 and 1911 hours*
  - *Mid-season: between 1464 and 3138 hours (if present)*
  - *Summer: between 3648 and 4056 hours*
  - *July-August: 1488 hours (if present)*
- **A-5 Long Use tarriffs** *(March 1995, FF 5 = $ 1)*
  - *Power Capacity Part:* *$ 95 per kW*
  - *Peak hours kWh price:* *$ 15.4 per 100 kWh*
  - *Empty summer hours:* *$ 2.4 per 100 kWh*
- **B-Modulate Average Use tarriffs**
  - *Power Capacity Part:* *$ 32 per kW*
  - *Peak hours kWh price:* *$ 28.3 per 100 kWh*
  - *Empty summer hours:* *$ 1.9 per 100 kWh*

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Power purchase tarriffs

- **Same complexity, but only one version** *(Very Long Use)*
- **A-5 tarriffs** *(February 1995, FF 5 = $ 1)*
  - *Power Capacity Part:* *$ 127 per kW*
  - *Peak hours kWh price:* *$ 9.5 per 100 kWh*
  - *Empty summer hours:* *$ 2.2 per 100 kWh*
- **B-Modulate tarriffs**
  - *Power Capacity Part:* *$ 99 per kW*
  - *Peak hours kWh price:* *$ 13.7 per 100 kWh*
  - *Empty summer hours:* *$ 1.8 per 100 kWh*
- **Average tarriffs (including power capacity part)**
  - *A-8 tarriffs, 3750 hours of furniture, $ 9.7 per 100 kWh*
  - *B-Modulate, 3750 hours of furniture, $ 9.0 per 100 kWh*
  - *B-Modulate, 5088 hours of furniture, $ 7.8 per 100 kWh*

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Projected improvements of cogeneration status

- ✓ Suppression of 8 MW limit (or significant raising)
- ✓ Possibility of direct local power sales by cogenerators
- ✓ Evolution of purchase tarriffs fixed for contract duration
- ✓ Revision of avoided costs formula (transmission costs)
- ✓ Revision of power failure penalities calculation
- ✓ New purchase tarriffs for cogenerators
  - ❑ *interesting if more than 5 000 hours of generation (industry)*
  - ❑ *one-part tarriff, without seasonal period*
  - ❑ *weekly programmation for guaranteed power*
- ■ Implementation of a cogeneration environmental bonus

Ademe

Decisions will be taken in the middle of 1996

GAS TURBINE SYSTEMS DEVELOPMENT TO MEET THE REQUIREMENTS OF A DUAL FUEL BIOMASS/DIESEL OIL APPLICATION

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Cogen INDIA '96
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GAS TURBINE SYSTEMS DEVELOPMENT TO MEET THE REQUIREMENTS OF A DUAL FUEL BIOMASS/DIESEL OIL APPLICATION

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This presentation describes the necessary systems development and modifications undertaken to supply an EGT TYPHOON gas turbine to operate on a gas fuel, produced by the gasification of wood waste (biomass gas fuel), with a lower calorific value in the range of 4.6 to 5.0 Mj/Nm^3.

The gas turbine combustion system is designed to operate on the biomass gas fuel and diesel oil. The system has been developed to be capable of starting on auxiliary fuel and operating around the required engine cycle, including on load change over.

An imposed restriction on the combustion system design has been to maintain physical interchangeability with the standard conventional TYPHOON combustion system.

The gas turbine has been installed and successfully run on biomass gas fuel at the Varnamo site in Sweden. This was a major breakthrough in alternative fuels technology by developing a gas turbine combustion system to operate on biomass gas fuel produced from wood waste by a process called pressurized gasification.

DANISH ENERGY POLICY WITH FOCUS ON COGENERATION ON STRAW AND GRID CONNECTION FROM SMALL COGENERATION PLANTS

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Danish Energy Policy with focus on cogenerationn on straw and grid connection from small cogeneration plants

Presentation on The First International Cogeneration Conference in India

"CogenIndia'96"

New Delhi, India, 11-12 March 1996

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Abstract

Since the mid eighties 6 completely or partly strawfired cogeneration plants have been built in Denmark. In addition a test-plant has been built and another is under construction. The annual straw consumption is 260,000 tons, from end 1996 380,000 tons. The testplant is now running for a 2 year period with up to 120,000 tons/year. The size of the cogeneration plants ranges from 2 MW to 30 MW electrical output.

In 1990 The Danish Ministry of Energy launched Energy 2000. It was an ambitious attempt to direct fuel consumption towards environmentally acceptable fuel types such as natural gas, solar energy, wind energy and biomass.

The plans objective is to achieve the following goals by the year 2005 compared to the situation in 1988:

- reduce energy consumption by 15%
- increase natural gas consumption by 170%
- increase renewable energy consumption by 100%
- reduce coal consumption by 45%
- reduce oil consumption by 40%
- reduce CO_2 emission by at least 20%
- reduce SO_2 emission by 60%
- reduce NO_x emission by 50%

These goals are to be achieved through an extensive conversion to cogeneration of energy in powerplants fuelled by natural gas and/or biomass.

According to regulation No. 6/1990 from the NAEP (National Agency on environmental Protection) on limiting air pollution from industries, the only emission limits for straw- and wood chip-fired plants larger than 1 MW are 40 mg/Nm^3 for solid particles and 0.05% CO (volume% at 10% O_2 in the flue gas) for CO emission. However, in the environmental approvals of the 7 plants, there are further individual restrictions on the emission of NO_x, SO_2.

To fulfill the Energy 2000 goals it is endeavoured also to develop biomass-fired gasifiers in the size of 0.5-5 MW electrical output.

The research effort in the gasification field is directed towards:

Development of technology for small gasifiers first for straw and later on for wood, both of which can supply a gas, sufficiently clean for motor fuel and with a comparatively high energy efficiency and economy.

The grid connection from small cogeneration plants can face heavy problems due to bad quality af voltage, frequency and $tg\varphi$.

In Denmark the specifications in a 10 kV systems are:

- voltage: 10 - 11 kV
- frequency: 49.0 - 50.3 Hz
- $tg\varphi$: -0.1 - 0.4

Normally the stiff grid in Denmark does not cause any trouble when small generators fulfilling the above limits are connected to the grid. In soft grids it is recommended to strenghten the specification of the generator according to electrical insulation and mechanical strength.

INTERNATIONAL EXPERIENCE IN BAGASSE-BASED COGENERATION

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THE FIRST INTERNATIONAL COGENERATION CONFERENCE IN INDIA

International Experience in Bagasse-based Cogeneration

Dan Jantzen
Renewable Energy Project Support Office
Presentation to the
1st Int'l Cogeneration Conference in India
March 11-12, 1996

World Tour of Power Exporting Sugarmills

- Brazil
- Central America
  - Costa Rica
  - El Salvador
  - Honduras
  - Guatemala
- Fiji
- India
- Mauritius
- Pakistan
- Philippines
- Reunion
- Thailand
- United States

Source: International Cane Energy News

Brazil

Mill	TCD	Inst. MW	Exp MW
Santa Adelia	10,000	8	1
Sao Martinho	35,000	19	1.6
Sao Francisco	6,700	3	0.3
Cresciumal	6,000	5.4	0.3
NS Aparecida	7,600	4.8	1
Santa Cruz OP	18,000	11.4	1.2
Ester	9,000	7.4	1
Vale do Rosario	17,000	16	4
Santa Elisa	22,000	13	5
Bonfim	20,000	14	1.2

Brazil

- World's largest producer of sugarcane
- Large, "world class" mills--sugar & ethanol
- Low power tariffs, no power investment
  - $0.018 in 1992
  - $0.041 in 1993
- State government, utilities and sugar industry task force planning expanded program

Central America

Mill	TCD	Export MW
El Viejo, Costa Rica	4,200	5
Izalco, El Salvador		1
Pantaleon, Guatemala	9,000	10
La Union, Guatemala	5,500	6
Concepcion, Guatemala	7,000	10
Madre Tierra, Guatemala	2,800	5
Santa Ana, Guatemala	6,500	8
Yojoa, Honduras		4

Central America

- Power tariffs of $0.04 to $0.07
- Sugar industry showing interest in power export
- A few mills adding equipment (new and used) for power export

Fiji

Lautoka: export 7.5 MW

Labasa: installing 10MW system. 5MW export

- Tariff $0.064 attractive to sugar industry
- Islands, limited power demand, supply is mainly hydro
- 4 sugar mills
- As power demand increases, cogen being integrated into the power system

India

- 5 small (1-3MW) exporters: Cheyyar, MRK, Dutta SSK, Jawahar SSK, Dhampur
- Thiru Arooran: 12.5 MW export
- Under construction: EID Parry, Dharani
- Some states offering Rs. 2.25=$0.065
- Growing interest
- Future growth depends on purchase terms

Mauritius

- Medine: 6 MW export
- FUEL, 22 MW export; coal and bagasse
- Union St. Aubin: 26MW export--long negotiations
- World Bank project for bagasse cogen
- Analyzing system of central power plant and satelite sugar factories

Pakistan

- Shakarganj, 3MW export
- Ashraf 4MW export
- Fatima, 3MW export
- Sell power "as and when available"
- 300 MW potential

Philippines

- Busco, export 8 MW
- Tarlac, collecting cane trash for fuel since 1987 using conventional hay balers
- Difficulties getting power sale contracts and reasonable prices

Reunion

- Bois Rouge, 60MW export; coal bagasse
- Beaufonds, 20MW export, bagasse
- Le Gol 64MW export, coal bagasse
- Utilize all the islands bagasse for power export and supplement with coal in off-season
- Utility participates in power plant ownership

Thailand

- 8 mills selling 2-4MW each on "as available" basis
- EGAT (utility) offers tariff based on capacity and energy but 5 yr contract required to receive capacity payment
- Energy wasted due to inability to negotiate acceptable contracts

United States

- Hawaii sugar industry in decline, several cogen plants closed, 5 cogen plants still operating
- 2 large plants under construction in Florida
  - Okelanta, 70MW installed capacity
  - Osceola, 55MW installed capacity

COMBUSTION OF LOW HEATING VALUE GAS IN A GAS TURBINE

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COMBUSTION OF LOW HEATING VALUE GAS IN A GAS TURBINE

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Advanced coal and/or biomass based power generation sytems offer the potential for high efficiency electricity generation with minimum environmental impact. An important component for many of these advanced power generation cycles is the gas turbine, for which development of a combustion system to burn low calorific value coal derived fuel gas, at turbine inlet temperatures of typically 1100-1260°C and with minimum pollutant emissions, is a key issue.

A phased combustor development programme is under-way burning low calorific value fuel gas (3.6-4.1 Mj/m^3) with low emissions, particularly NOx derived from fuel-bound nitrogen. The first and second phases of the combustor development programme have been completed. The first phase used a generic tubo-annular, prototype combustor based on conventional design principles. Combustor performance for this first prototype combustor was encouraging. The second phase assessed five design variants of the prototype combustor, each variant achieving a progressive improvement in combustor performance. The operating conditions for this assessment were selected to represent a particular medium sized industrial gas turbine operating as part of an Air Blown Gasification Cycle (ABGC). The test conditions assessed therefore included the capability to operate the combustor using natural gas as a supplementary fuel, to suit one possible start-up procedure for the cycle.

The paper presents a brief overview of the ABGC development initiative and discusses the general requirements for a gas turbine operating within such a cycle. In addition, it presents full combustor performance results for the second phase of turbine combustor development and discusses the rationale for the progressive design modifications made within that programme. The strategy for the further development of the combustor to burn low calorific value fuel gas with very low conversion of fuel-bound nitrogen to NOx is presented.

COMBINED HEAT AND POWER IN IEA MEMBER COUNTRIES

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Combined Heat and Power in IEA Member Countries[1]

by
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International Energy Agency

Abstract
Combined Heat and Power (CHP) plants generate a relatively small share of IEA electricity supply — 11.7% of fossil fuel-based production in 1993. There is potential for increased CHP use because of energy demand growth, increasingly stringent environmental obligations, and technical advances and cost reductions in CHP technology: many IEA Member countries are anticipating significant increases CHP capacity through the end of the decade. CHP is attractive from an energy policy viewpoint, because it is capable of producing electricity and heat with lower capital and fuel costs, reduced pollution, and increased fuel diversity. However, the reality is very site-specific: not every potential CHP site delivers all these benefits. Most IEA Member governments have tried to increase their countries' use of CHP through information and audit programmes, rules governing CHP relationships with utilities, financial incentives, and support for research and development. However, these policies do not seem to explicitly or logically reward those features of CHP, specifically environmental compatibility and energy efficiency, which are used to justify policy intervention in the first place. This paper outlines the technical, economic, and institutional factors that fosters CHP use, and reviews the IEA government programmes used to promote its development.

I. INTRODUCTION

Combined heat and power production (CHP) has undergone several periods of growth and decline in its century-long history. In the early decades, the inherent wisdom of using the heat otherwise exhausted during electricity generation and the limited availability of electricity in non-urban areas in most countries, encouraged CHP. Later, economies of scale in the production of electricity through conventional thermal cycles led to the construction of larger and more efficient power generation facilities sited farther and farther from both population centres and industrial facilities. This both expanded the market for grid-supplied electricity and limited the market for heat exhausted from power stations, by increasing the distances over which the waste heat would need to be transported. Thus CHP fell from favour for all but a few applications.

Interest in CHP rebounded between the mid-1970s and early 1980s. The two oil shocks focused attention on ways to cost effectively reduce energy waste. Second, the scale of conventional power plants began reaching a point of diminishing returns. Third, advances in the efficiency of CHP systems improved

1. The views expressed in this paper are those of the author. They do not necessarily reflect the official position of the International Energy Agency or of the governments of IEA Member countries. The material is drawn from an unpublished IEA working paper, *Combined Heat and Power Generation in IEA Member Countries*, October 1994.

their cost effectiveness, especially for smaller applications. Member countries of the International Energy Agency (IEA)[2] responded to the promises of this technology by promoting its growth through: information campaigns; technical audits; financial incentives for the installation of CHP systems; requirements that utilities purchase power from, and provide back-up power to, users of CHP systems (sometimes at preferential prices); preferential gas transportation prices; and forgiveness from environmental licensing requirements for plants below a certain generating capacity (corresponding to an air emissions threshold level).

The popularity of CHP declined again somewhat during the mid-1980s, as falling real energy prices diminished the financial attractiveness of CHP and reduced the importance that some countries attached to increasing its use. Moreover, the electricity supply/demand balance in some countries reduced the importance of new capacity from CHP systems. The lower energy prices and abundant electric generating capacity reduced the "avoided cost" which some countries use as the basis for evaluating the cost-savings associated with electricity and heat produced by CHP plants. Furthermore, the improved efficiency of gas-turbine generating systems led to a class of independent power producers capable of competing with electric utilities on electricity production alone — without the need to use or sell the heat.

More recently, concerns about the potential environmental impacts of energy use have refocused attention on strategies for reducing the emissions of a variety of pollutants, especially CO_2. CHP systems are attractive in this context, because in many circumstances they can produce a given amount of electricity and useful heat more efficiently, and presumably with lower emissions, than can conventional facilities — separate electricity generators and boilers. However, as is discussed in the next section, CHP's claim as an environmentally preferred method for producing electricity and heat requires thorough examination of many site-specific factors.

II. BEYOND THERMODYNAMIC EFFICIENCY: ENERGY, ENVIRONMENT, ECONOMICS, AND INTEGRATION WITH UTILITIES

In general, CHP systems can convert approximately 75-80% of the energy content of fuel into useful electricity and thermal energy. Though impressive, especially compared with conventional electric production systems at 30-40% and even new combined-cycle gas turbine systems capable of up to 52%, such general efficiency estimates do not take account of the very different storage, transport, market, and reliability

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2 The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. IEA participating countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway (by special agreement), Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The Commission of the European Communities also takes part in the work of the IEA. Iceland and Mexico are members of the OECD, but not the IEA. Six OECD Member countries — Australia, Canada, Japan, Mexico, New Zealand, and the United States — are members of the Asia Pacific Economic Cooperation group

requirements of the two products — electricity and heat (Verbruggen 1992, 1993). Nor do they give a clear picture of CHP's energy, environmental and economic characteristics, which interest policy-makers and investors. This section discusses some of the many factors that affect the energy savings, environmental benefits, project economics, and integration with utilities.

A. Energy Savings and Environmental Benefits

The energy savings and environmental benefits of CHP are very site specific. They depend upon the form and quantity of fuels CHP systems use and displace, and on the emissions controls that the CHP and alternative systems employ. An example might be one in which municipal solid waste would be burned in order to generate electricity and heat, the latter being distributed to an adjacent community, with the alternative being the production of electricity in a fossil fuel-fired power plant combined with individual space heating by natural gas. Or perhaps, if a district heating CHP system relies on coal to provide heat to buildings which would have otherwise consumed natural gas, each system has the potential to produce a different mix and quantity of emissions at different locations, with the gas-using systems having an apparent advantage. However, central plants can be equipped with tall stacks and flue gas cleaning devices in order to minimise the potential environmental disadvantages.

Further, the potential energy-efficiency gains of CHP need to be determined via a thorough examination of the purposes to which the waste heat is being employed as compared with the alternatives. It is often accepted at face value that all of the heat produced or displaced by the CHP system is "useful." CHP systems can frequently be oversized relative to the existing load and/or relative to the "efficient" load (i.e., the energy required to perform the service using a device more efficient than the incumbent). The former results in the unnecessary exhaust of waste heat, while the latter results in the capture of waste heat which is subsequently lost in, for example, poorly insulated pipes.

B. Project Economics

The economics of CHP at a given location are based on the physical features of the site, the building or industrial process into which the CHP system is to be integrated, and the energy sources (and prices) available for both CHP and the alternative. Although the following factors are not pre-conditions for the successful development of CHP for a specific application, they can contribute to the project's overall attractiveness:

- relatively constant and well-balanced requirements for heat and electricity;
- favourable physical site conditions, e.g., short distances for heat transport;
- a low-cost supply of fuel, e.g., wood waste at a paper-processing plant;
- correspondingly higher costs for separately supplied heat and electricity;

- energy costs that represent a significant share of total operating costs; and
- operator experience with CHP or electricity generation.

Relatively constant and well-balanced requirements for heat and electricity are an especially important consideration because of the "real-time" nature of electricity and thermal needs and production. The existence of an electric grid that will purchase surplus electricity and provide back-up power gives important flexibility to the design and operation of a CHP system, allowing the electricity output of the CHP system to be essentially physically decoupled from the site's needs. Without a grid, the selection and design of the CHP system is driven by a need to follow the electric and thermal requirements of the site simultaneously — not an easy task for CHP systems which have relatively fixed output ratio's between these two products. The existence and expected persistence of a "base load" thermal requirement is also very important. For industrial applications, constantly changing industrial technologies and processes and changing plant configurations (i.e., consolidations and closures) will limit the number of sites suited to CHP.

CHP plants typically require the investor to incur incremental up-front costs relative to the alternative (in most cases, production of heat and purchase of electricity) in order to reduce operating costs. The investment considerations faced by a potential CHP facility owner/user are similar to those for conventional investments in energy efficiency equipment: limited financial resources and competing appeals for capital; limited technical and cost-benefit information; short investment horizons, particularly for individual investors; and split incentives between investors and users of energy equipment that encourage first-cost minimisation to the possible detriment of energy-related savings over time.

However, CHP has four features that distinguish it from end-use efficiency investments. First, CHP produces two products — electricity and thermal energy — that are relatively familiar, uniform and present in most facilities. Second, CHP plants do not affect critical parts of the production process, as might be the case with other efficiency measures. Third, CHP systems affect a relatively larger share of a facility's energy requirements through a single investment, as compared with motors, lighting systems and HVAC. Finally, because of the high capital costs, CHP investments are more likely to be championed by a person or department responsible for total facility energy costs and in a position to evaluate the energy consequences of different plant investments.

Under certain circumstances, it becomes preferable for an independent business entity to invest in CHP and sell the electric and thermal products to one or more users (including the electric utility). Third-party investors may bring certain strengths to the project, such as financial leverage, financial flexibility, tax advantages, risk diversification, and operating expertise. The existence of different parties requires a more explicit consideration of the value of the electricity and thermal energy produced, although the basic financial decision remains grounded on a comparison between an initial investment and an associated annual cash flow.

C. Integration with Electric Utilities

Though most CHP systems are developed by entities other than an electric utility, the economics of CHP projects are affected greatly by the form of electric utility structure and the institutional, commercial and legal relationships between the utility and owners of non-utility generation. The manner in which CHP systems interact with electric utilities must be viewed against the backdrop of the utility ownership and regulatory system within the country[3]. At the core of this relationship are two issues: 1) commercial considerations, including two-way sales of electricity and capacity between the CHP owner and utility; and 2) obligations of CHP owners to operate as part of an integrated system.

Commercial Integration — CHP systems owned by non-utilities may be sized, designed and operated to: i) provide as much of the site's electricity needs as possible; ii) sell output to the grid; or iii) a combination of the two. The decision depends largely on the relationship between the utility's tariffs and marginal costs. From the perspective of the CHP owner, the prices charged by the utility represent the costs which can be "avoided" by the CHP system, while the utility's marginal cost is typically the basis, or in some cases the ceiling, for payments made to power suppliers. Although this relationship will change over time, retail prices, inclusive of transmission and distribution capacity costs, are typically higher than the generation-based payments to independent power suppliers. Thus, supplying power to satisfy the site's needs is usually more attractive than selling the same power to the grid, although the grid can certainly be a valuable "sink" for excess power.

In addition, those served by a CHP system will also need to purchase power from the utility for maintenance, back-up, or supplemental reasons, unless the site is grid-independent by either choice or circumstance. From the perspective of the electric utility, provisions need to be made for periods when the CHP system is unavailable; choices include either the installation and maintenance of redundant capacity — which carries a cost — or plans for curtailing the load.

Physical Integration — Under most forms of utility ownership and regulation within the IEA, generation utilities are granted certain rights in exchange for certain responsibilities. Owners of CHP systems, whether producing electricity for own-use or sale, typically do not have the same obligations. Thus, under the familiar vertically integrated structure, utilities' generation planning and operation becomes more complicated and administratively costly when CHP systems operate somewhat independently of the planning and dispatch functions of the utility. Commercial contracts for power purchases by the utility can be designed to ameliorate some of the utility's risk, by offering terms and conditions that reflect the value associated with different services offered by power plants. These may include incentives for: availability during the utility's peak periods; reliability during system emergencies; voltage and frequency support; and system longevity and/or penalties for early retirement.

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3. (CEC 1993) provides a review of utility attitudes toward CHP within the European Union.

Some countries are changing the structure of their electric supply industries in order to introduce competition into the generation, and in some cases, the supply of electricity (IEA 1994b). Under such circumstances, the planning and dispatch of electricity are likely to be dictated increasingly by market forces rather than regulatory or government fiat. It is expected that this will open up additional opportunities for CHP in those systems that have been closed to independent power production. Conversely, in those systems that have provided financial support for CHP in the form of guaranteed power purchases at attractive prices, the increased competition may serve to limit or eliminate the guarantees.

III. CHP APPLICATIONS AND ROLE IN ENERGY SUPPLY

CHP is used most extensively in industrial facilities, such as petroleum refining, chemical, metallurgical, pulp and paper mills and food-processing plants that commonly have high steam demands and abundant combustible byproducts. CHP is also used in district heating systems, serving residential, commercial and occasionally industrial loads. And recently, inroads have been made into various subsectors of the commercial market, including hospitals, hotels, health clubs, universities, laundries and multi-unit residential buildings.

Table 1 shows the shares of CHP electricity produced by public suppliers (privately or publicly owned companies that, as their primary activity, generate electricity and/or heat for sale to third parties) and autoproducers (companies that generate electricity and/or heat, wholly or partly for their own use in support of a different primary activity). Public suppliers typically use CHP for district heating applications and autoproducers typically use it for industrial applications. The table shows that in some countries nearly all of CHP production is by autoproducers (e.g., Australia, France, Greece, Ireland, Portugal, Spain and the United Kingdom); in others nearly all the facilities are operated by public entities (e.g., Belgium, Denmark, Iceland, the Netherlands and Norway). The table also points out that CHP data is not reported in quite a few IEA Member countries, including several APEC members.

A. Industrial Applications

Industrial sites (petroleum refining, chemical, metallurgical, pulp and paper mills and food-processing plants)are the most traditional hosts for CHP facilities. This is due to several factors: significant thermal requirements that are process-related and not subject to daily and seasonal weather-related fluctuations[4]; sites that are typically zoned for power production; availability of low-cost fuel sources in a number of industries (e.g., wood waste in pulp and paper mills); operations and maintenance personnel with competence in power systems; and energy-cost reduction goals that are aligned with strategic business interests.

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4 In countries with mild climates, there are very few applications of CHP outside of industry.

Table 1
Shares of CHP Electricity Generation, 1993
(per cent)

	Autoproducers	Public Producers
Australia	100	0
Austria	--	--
Belgium	0	100
Canada*	--	--
Denmark	1	99
Finland	47	53
France (1990)	84	16
Germany**	--	--
Greece	100	0
Iceland	0	100
Ireland	100	0
Italy	96	4
Japan	--	--
Luxembourg	0	0
Mexico	--	--
Netherlands	20	80
New Zealand	100	0
Norway	0	100
Portugal	83	17
Spain	100	0
Sweden	41	59
Switzerland	61	39
Turkey	100	0
United Kingdom	100	0
United States	76	24
Total OECD	63	37

-- indicates data not available.
* Country report in IEA 1994 (shown in Appendix) states that most CHP production comes from autoproducers.
** Country report in IEA 1994 shows 58% of CHP capacity at autoproducers and 42% at district heating facilities in 1990.

Figures are *estimates* of shares of CHP electricity production. The underlying statistics count all output from electricity plants having CHP units as CHP production, even in cases where CHP units represent a small portion of a plant's capacity and where CHP units are not always run in CHP mode.

Source: IEA/OECD Electricity Statistics and country reports in IEA 1994.

A representative of independent power producers has expressed the requirements for further development of CHP systems in industry as follows (Hamrin 1988):

- Clear and equitable interconnection specifications to the electric grid;
- Unbiased electricity standby rates and demand charges;
- Stable fuel supply;
- Stable regulatory environment;
- Predictable and sufficient revenue stream; and
- Power purchase agreements that are financeable (without open-ended liabilities).

Two factors need special attention when contemplating the viability of CHP in industrial settings: the expected persistence of the thermal loads, and the tolerance and back-up for CHP system outages. Constantly changing industrial plant configurations (including consolidations, closures and the introduction of new electric-based technologies) will limit the number of sites suited to CHP. It is not at all clear that the thermal load at a given industrial site will endure at the quantities necessary to ensure the financial success of the project. Regarding system outages and availability, depending upon the technology employed and the manner in which it is maintained, the system may be more or less prone to scheduled and unscheduled outages. While back-up electricity is normally available from the grid, different types of industrial facilities have different levels of tolerance for the loss of thermal load. Typical responses are attempts to "coast through", shut down production, or maintain redundant thermal capacity. These latter two entail costs.

Finally, the availability and price of natural gas, the fuel of choice for many systems due to the efficiency and cost improvements to gas turbine-based CHP systems, will influence the level of CHP development for this market.

B. District heating

District heating (DH) systems, in which steam or hot water is produced in centralised plants and circulated to end users through a piping network, tend to be built around the same basic concepts that led to centralised production and distribution of electricity: economies of scale, diversity in use (load timing) and increased efficiency[5]. Moreover, DH offers additional advantages over the use of individual heating equipment. The most notable being the ability to take advantage of low-cost fuels, such as municipal solid waste, biomass and waste heat from a CHP facility, which may not otherwise be available (or practical) for individual users. Additionally, it is more straight-forward to switch fuels at a centralised location as opposed

5 The efficiency advantages of DH systems, with the exception of those based on CHP, have largely diminished, particularly with the introduction of condensing boilers. Moreover, DH systems have additional heat losses of approximately 5-12%, depending on the quality of the piping and insulation, the temperatures of the send-out and return, and the thermal density of the network

to number of individual heating systems. This introduces an energy-security dimension to DH systems. However, fuel diversity and flexibility become somewhat less significant when CHP systems are based on combustion turbine or reciprocating engine technologies, since these tend to rely upon natural gas or light distillates.

The overwhelming predominance of the distribution-related capital costs leads to two characteristics of DH systems: 1) they are more common in areas that have heat requirements amenable to the minimisation of these costs, e.g., high thermal density and relatively balanced thermal load on a daily and seasonal basis, and 2) they tend to require some level of government involvement to become established. In most regards, the decision to install a CHP plant as part of a DH system will depend on many of the same factors as is applicable to an industrial installation, including: the timing and nature of the thermal load, fuel availability, and opportunities for the economic use of the electricity. However, the different settings into which these systems are introduced, will lead to a different set of ownership, market impact, decision making, heat delivery, grid connection, load pattern, and technology preference characteristics.

C. Residential and Commercial Systems

Developments in CHP technology over the past 10 years have lead to the introduction of small-scale systems that can, under selected circumstances, meet the needs of commercial buildings or multi-residential dwelling complexes. Some of these users have energy requirements similar to those of the energy-intensive industries discussed earlier — balanced and constant electric and thermal loads, energy costs that are a significant share of the total operating costs, etc. These conditions exist year-round in hospitals, hotels, laundries and health clubs, but only seasonally in schools.

The advances in CHP technology that have led to in-roads in these markets include smaller-scale, typically engine-based, systems, prepackaged designs (in order to reduce capital and installation costs), sound attenuation devices, standardised electrical connections, simplified maintenance requirements, and environmental controls. These systems are usually fuelled by natural gas. In some cases, the systems have been combined with absorption chilling units in order to increase the opportunities for using the waste heat.

As discussed previously, CHP implementation is limited by the same factors that influence the adoption of energy-efficiency technologies. This is particularly true in the commercial and residential sectors, where institutional arrangements tend to result in a first-cost focus on the part of the building developer, with on-going responsibility for energy costs being assigned to the building owner/manager or users.

D. Role of CHP in Electricity Supply

Table 2 shows the contribution of CHP to electricity supply. It should be noted that the quantities of electricity reported in this table do not reflect the extent to which the power plants were actually operated in the CHP mode. Since plants designed as extraction/condensing can be operated entirely in the condensing

Table 2

CHP share of electricity supply

	Production 1993 (except where noted)			**Capacity 1990** (except where noted)		
	CHP electricity production (TWh)	**Share of total electricity supply**	**Share of fossil fuel electricity supply**	**CHP electricity capacity (GW)**	**Share of total electricity capacity**	**Share of fossil fuel electricity capacity**
Australia	6.1	3.7%	4.1%	--	--	--
Austria	2.5* (1990)	5.0%*	13.8%*	0.8**	4.9%**	15.8%**
Belgium	7.2	10.2%	26.0%	1.8	12.7%	24.9%
Canada	--	--	--	2.0 (1989)	2.0%	6.9%
Denmark	29.3	86.7%	89.5%	5.0	57.0%	55.7%
Finland	19.9	32.5%	71.7%	--	--	--
France	4.0 (1990)	1.0%	8.4%	1.6	1.6%	9.6%
Germany	52.0 (1990)	9.5%	13.4%	18.7	14.8%	20.7%
Greece	0.8	2.2%	2.4%	--	--	--
Iceland	--	--	--	--	--	--
Ireland	0.2	1.3%	1.4%	0.1	1.5%	1.8%
Italy	23.4	10.5%	13.4%	--	--	--
Japan	--	--	--	2.3 (1992)	1.1%	1.7%
Luxembourg	0.0	0.0%	0.0%	0.0	0.0	0.0
Mexico	--	--	--	--	--	--
Netherlands	72.8	94.5%	100.0%	3.3	21.5%	22.3%
New Zealand	--	--	--	0.2 (1994)	2.1%	7.2%
Norway	0.1	0.1%	23.1%	--	--	--
Portugal	2.6	8.3%	11.5%	0.7	9.5%	17.4%
Spain	3.6	2.3%	4.8%	1.0	2.2%	4.7%
Sweden	8.8	6.0%	95.9%	--	--	--
Switzerland	1.1	1.8%	89.8%	0.8	5.1%	62.5%
Turkey	--	--	--	--	--	--
United Kingdom	14.2	4.4%	6.2%	2.0	2.7%	3.5%
United States	335.8	9.8%	13.8%	49.0	7.1%	9.8%
Total OECD	584.3	7.6%	13.0%	--	--	--

-- indicates data not available.
* IEA estimates.
** DH systems data and do not include industrial or commercial CHP.

Source: IEA/OECD Electricity Statistics, country reports in IEA 1994, and UNICHAL (1991).

mode, electricity output from a CHP facility does not imply that waste heat was actually used. Moreover, the entire production of any power plant that includes a CHP unit is counted as CHP production, even if the unit represents a small share of the total plant capacity.

CHP does not represent a significant share of the total electricity supply for any country, with the exception of the Netherlands, Denmark, and Finland. However, CHP production is more appropriately compared with fossil fuels-based electricity supply, since most CHP is based on fossil-fuel technologies, for which some level of siting discretion exists[6].

Fossil fuels contributed 58.9% to electricity supply in OECD countries in 1993, and CHP contributed 13.0% to fossil-fuelled electricity production in 1993[7]. Of the 16 countries that reported CHP production information in 1993, CHP's contribution to total fossil electricity supply is greater than 70% for five countries, between 10% to 30% for five countries, and below 10% for six countries.

The five countries where CHP provides greater than 70% of the fossil fuel-based supply are the Netherlands, Sweden, Switzerland, Denmark, and Finland. While Swiss and Swedish fossil-fired electricity production is based largely on CHP, this must be viewed in light of the fact that fossil-fired electricity production is a very low percentage of total electricity production in these countries — 2% and 6%, respectively. In contrast, the fossil-fired electricity represents a significant share for the Netherlands, Denmark, and Finland. In the Netherlands and Denmark, electricity production is almost entirely supplied by fossil fuels — 95% and 97%, respectively, and the 100% CHP share in the Netherlands and the 90% CHP share in Denmark represents an important contribution to the national electricity supply in these countries. In Finland, 45% of electricity production is fossil-fired, and 72% of this is supplied by CHP.

Regarding the mix of fuels employed by CHP systems, Table 3 indicates the fuel sources for CHP plants and fossil-fired electricity-only plants. As would be expected, autoproducer CHP plants use a much higher share of natural gas than public CHP plant use. In addition, compared with fossil-fired electricity-only plants, CHP facilities uses a much higher share of natural gas and solid fuels such as wood and wastes.

E. Outlook for CHP in Electricity Supply

Table 4 provides estimates for future electricity production through CHP. A sampling of the types of projects being installed include relatively large plants, many over 100 MW_e, a large number of which are gas fired. The most dramatic increase in electricity production is expected in the **Netherlands**, where the supply is expected to more than double by the year 2000. This table implies an increase of approximately 8.2 GW of CHP capacity among those countries reporting.

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6 In Switzerland, two nuclear facilities are operated in a CHP mode, providing heat to a factory and district heating system, respectively.

7. Data on CHP were not available for all OECD countries. All generalisations about the share of CHP are based on an extrapolation from those countries for which data was available.

Table 3

Fuel Shares for CHP-Autoproducers, CHP-Public Producers, and Electricity-only Producers, 1993

(per cent)

	CHP - Autoproducers				CHP - Public Producers				Fossil Fuel Electricity-only Producers			
	Coal	Other Solid Fuels	Oil	Natural Gas	Coal	Other Solid Fuels	Oil	Natural Gas	Coal	Other Solid Fuels	Oil	Natural Gas
Australia	--	--	--	--	--	--	--	--	88.8	0.0	1.9	9.4
Austria	--	--	--	--	--	--	--	--	33.2	0.0	13.7	53.2
Belgium	--	--	--	--	78.3	0.2	10.8	10.8	57.4	6.5	3.8	32.3
Canada	--	--	--	--	0.0	0.0	31.0	69.0	76.2	1.5	9.6	12.7
Denmark	19.6	4.9	53.9	21.6	87.1	3.8	3.1	6.0	85.6	1.9	9.4	3.1
Finland	17.2	59.3	6.7	16.7	45.2	23.8	3.0	28.0	55.2	29.7	3.9	11.2
France	--	--	--	--	--	--	--	--	75.8	2.4	14.7	7.0
Germany	--	--	--	--	--	--	--	--	87.2	1.2	2.8	8.8
Greece	0.0	25.1	60.9	14.0	--	--	--	--	79.6	0.0	20.4	0.0
Iceland	--	--	--	--	--	--	--	-	0.0	0.0	100.0	0.0
Ireland	16.1	22.6	5.9	55.4	--	-	-		38.7	16.1	15.7	29.5
Italy	4.9	1.6	42.3	51.2	10.9	5.5	25.8	57.9	12.9	0.2	66.6	20.3
Japan	--	--	-	-	--	-	--	--	27.9	1.9	37.3	32.9
Luxembourg	--	--	--	--	--	--	--	-	78.1	12.6	5.9	3.4
Mexico	-	--	--	--	--	--	--	--	11.1	0.0	72.5	16.4
Netherlands	4.1	9.6	20.3	65.9	41.1	0.1	0.4	58.4	--	--	--	-
New Zealand	--	--	--	--	--	--	--	--	6.2	0.0	0.8	93.0
Norway	--	--	--	--	28.0	72.0	0.0	0.0	40.9	59.1	0.0	0.0
Portugal	9.6	35.8	54.6	0.0	0.0	0.0	100.0	0.0	56.4	0.0	43.6	0.0
Spain	17.7	8.5	53.4	20.4	--	--	--	--	87.5	0.3	11.9	0.3
Sweden	4.0	52.3	37.5	6.2	33.9	30.5	21.2	14.3	9.4	0.0	90.6	0.0
Switzerland	0.0	24.3	33.3	42.4	0.2	78.4	8.1	12.3	--	--	--	--
Turkey	--	--	--	--	--	--	--	--	62.2	0.4	15.6	21.9
United Kingdom	22.1	5.6	22.5	49.8	--	--	--	--	75.3	0.9	10.7	13.2
United States	26.1	26.6	6.1	41.3	71.3	0.2	16.6	12.0	79.1	2.0	4.6	14.4
Total OECD	24.5	25.3	8.5	41.7	60.6	4.7	9.6	25.1	68.6	1.7	13.6	16.2

-- indicates data not available.

Figures are based on *estimates* of shares of CHP electricity production The underlying statistics count all output from electricity plants having CHP units as CHP production, even in cases where CHP units represent a small portion of a plant's capacity and where CHP units are not always run in CHP mode. Coal includes coke oven and blast furnace gas, other solid fuels include peat, wood, wastes, and other solid fuels; oil includes all liquid fuels and refinery gas, and natural gas includes gasworks gas.

Source IEA/OECD Electricity Statistics

Table 4
Outlook for CHP in the year 2000
(Figures in parentheses show CHP share of total electricity production or capacity)

	CHP electricity production (TWh)		CHP electricity capacity (GW)	
	1993 except where noted	**2000**	**1990** except where noted	**2000**
Australia	6.1 (3.7%)	9.2	--	--
Canada	--	--	2.0 (2.0%) 1989	5.1 (3.7%)
Finland	19.9 (32.5%)	28.5 (36.1%)	--	--
Ireland	--	--	0.1 (1.5%)	0.1 (2.7%)
Netherlands	18.0 (25.0%) 1990	44.0	3.3 (21.5%)	8.0 (39.0%)
New Zealand	--	--	0.2 (2.1%) 1994	0.7 (7.7%)
Spain	--	--	1.0 (2.2%)	2.2 (4.4%)
Switzerland	1.1 (1.8%)	1.9 (3.0%)	0.8 (5.1%)	0.8 (6.7%)
United Kingdom	--	--	2.0 (2.7%)	4.0 (5.0%)
TOTAL	--	--	12.7	20.9

Note. The potential electricity supply from CHP for Australia is estimated for an unspecified year. CHP electricity supply for Switzerland in 2000 is based on the estimated growth rate.

IV. GOVERNMENT SUPPORT OF CHP

Most IEA Member governments have tried to increase their countries' use of CHP through information and audit programmes, rules governing CHP relationships with utilities, financial incentives, and support for research and development. The motivation behind these measures is the desire to exploit the potential efficiency benefits of CHP and to diversify sources of electricity production, as well as the belief that impediments in the marketplace will prevent the appropriate level of CHP from being realised.

Some governments have elected to "tilt" the field in favour of CHP, in part because it is an "infant" industry and needs some degree of protection in order to develop. Similarly, the high capital costs of DH systems have lead some governments to assist with the up-front financing and to absorb some of the risk that the system becomes fully subscribed. Under selected circumstances, governments have taken steps to minimise this risk by "guaranteeing" a customer base. Other governments have intervened because the playing field was thought to be biased against CHP systems (e.g., utility recalcitrance to interconnect with them). In these cases, government efforts to promote CHP have generally tried to remove potentially discriminatory treatment vis-a-vis electric utility policies.

It should be noted, however, that little evidence shows that the government policies are designed so as to reward a particular attribute of CHP, such as efficiency or environmental compatibility. Many governments appear to support CHP on the basis that it provides a public good, and do not require individual projects to demonstrate efficiency advantages, in either design or operation, to qualify for the policy benefits.

Noted exceptions include the US rules on efficiency requirements for a system to achieve "qualifying facility" status; Italian payment premiums from utilities to systems that exceed a stated efficiency level; and Canadian tax support for CHP systems that have heat rates less than a specific target.

The different types of governmental approaches — information, institutional, financial and R&D — employed to support CHP are discussed below. Of course, these should be viewed in light of the countries' energy resource endowments and their governments' role in energy policy. Caution is also recommended before inferring any cause and effect relationship between these measures and the degree to which CHP contributes to electricity production. Other factors are obviously instrumental in influencing CHP development, for example: industry mix, urban density, and heating degree days.

A. Information and Feasibility Studies

Many governments of Member countries provide information on CHP systems. For example, **Germany** provides leaflets, brochures and books and the **Netherlands**, **Switzerland** and the **United Kingdom** provide project profiles and case studies.

Several governments underwrite the costs of feasibility studies for CHP in given applications. **France** and **Italy** provide up to 50% of the cost of the feasibility study. The **Netherlands** provides 50% of the cost of the evaluation, up to Gld 50 000. **Turkey** funds industrial audits, while the **United Kingdom** provides financial assistance for consulting services on identification, design and management of projects that have a "good chance" of providing energy savings in excess of 10%.

B. Institutional Arrangements

The most common type of institutional support offered by member Governments is the requirement that utilities connect to and purchase power from CHP systems. In some cases, the rates at which the power is purchased is specified or set by formula. In 1980 only Austria, Italy and Spain, provided legal rules to connect co-generation plants to the electric grid. As of 1992, ten countries had granted legal rights to autoproducers to sell electricity to the local utility (see Table 5). The purchase prices are often based on avoided costs. Price controls are often added, and can be implemented in one of three ways:

- prices legally fixed (Italy);
- prices reviewed by committees (government committees or those consisting of different groups, including manufacturers and electric utilities); and
- prices based on specific projections by a governmental institution (United States).

Table 5
Right to sell surplus electricity from CHP plants and prices for electricity fed into the grid

Country	Right to sell electricity	Typical price	Price control
Australia	Yes	peak — 9.03 cents	Incentive
Austria	Yes	Avoided costs	By decree
Belgium	Yes	Avoided costs	Review
Canada	--	--	--
Denmark	Yes	0.3 DKr/kWh	Regulated by act
Finland	--	--	Determined by all users
France	Yes	Set relative to utility prices	By decree
Germany	Association agreement	0.08-0.1 DM/kWh	--
Greece	--	--	--
Ireland	Yes	Avoided cost	--
Italy	Yes	37-137 L/kWh	Fixed by decree
Japan	--	--	--
Luxembourg	--	--	--
Netherlands	Yes	Avoided cost	Review commission
New Zealand	Yes	Negotiated by buyers and sellers	None
Norway	--	--	--
Portugal	Yes	Incentive	By decree
Spain	--	--	--
Sweden	Yes	Avoided cost	Review
Switzerland	Yes	Other new plant	--
Turkey	--	--	--
United Kingdom	Yes	Pool prices	--
United States	Yes	Avoided cost	Contract for each new plant

Source: Country reports in IEA 1994.

The **Netherlands** and **Italy** have recently allowed utilities to enter into joint ventures with industrial partners — the Netherlands even encourages such joint ventures. Most of the CHP estimated in **Belgium's** industrial sector are expected to come about through joint-venture projects between ELECTRABEL and several industrial partners (CEC 1992).

Some countries have instituted requirements that buildings in the proximity of a DH network be connected to the system. The motivation is to shelter the DH system during the early years when capital expenditures are high and revenues low, with the expectation that the fully-developed system will provide lower cost energy than the alternatives. For example, **Denmark** reserves about 60% of the heating market for DH and eventually CHP. Residential buildings exceeding 250 KW of demand and in the proximity of either a DH or natural gas network are required connect to one or the other.

In 1990, **Denmark** established a policy that all new electric capacity through the mid-1990s be achieved primarily through the conversion of existing DH heat-only plants into small-scale CHP plants fuelled by gas, refuse or biomass. As a consequence, the development of a coal-fired facility was changed to gas. Each district council must prepare a plan for the supply of heat in the municipality, with the requirement that all heat supply systems in excess of 1 MW be analysed for conversion to CHP.

Some countries allow CHP systems to use fuels that are otherwise constrained for power generation. For example, **Portugal** limits the use of oil products for the production of electricity (per EEC Directive), but relaxes the rule for CHP systems, if they have a permit based on an analysis of alternative fuels. In the **United Kingdom**, government authorisation is required to use natural gas for power generation. CHP plants and combined-cycle gas turbines normally receive this authorisation.

C. Financial Incentives

Several member governments provide financial incentives to developers of CHP systems. The incentives are either grants based on installed capacity or operating efficiency, or tax incentives. **Canada** offers preferential tax treatment for capital depreciation for energy efficiency equipment. CHP systems with net heat rates of 7 000 Btu/kWh or less, qualify for an accelerated write-off schedule of 25%, 50%, 25%. **Denmark** offers an investment subsidy of up to 30% of total investment costs for CHP in industry and greenhouses. **France** provides an exemption on fuel taxes for gas and low-sulphur heavy fuel oil used in CHP plants, an exemption of 50% of the professional tax on the asset value of the plants, and a possibility of accelerated amortization for the investments. **Italy** provides investment support of up to 40% of the capital cost for CHP systems with capacity in excess of 10 MW_{th} or 3 MW_e, and up to 50% for DH systems recycling heat from electricity production or industrial processes. **Japan** offers low-interest loans (between 6 to 7%) and a choice among tax incentives. **Luxembourg** provides financial incentives of 25% of the costs of systems that "promote energy saving in general" or use new and renewable energy resources (up to LF 60 000). The **Netherlands** provides up to 25% of the investment costs for CHP schemes in industry, commercial buildings and horticulture (up to Gld 500 for engines and Gld 650 for gas or steam turbines below 2 MW_e, not to exceed Gld 20 million per project). **Portugal** provides financial assistance to CHP schemes through the SIURE Program (System of Incentives for the Rational Use of Energy). **Sweden** grants a fixed subsidy per kW_e of installed capacity of CHP (Skr 4 000) for systems that are fuelled by bio-fuels. CHP systems are forgiven on energy taxes, although the share of the fuel that can be assigned to heat production is still subject to the CO_2 tax. In the **United Kingdom**, "own-generation" systems that consume more than 51% of the electricity on-site are exempt from the 11% fossil fuel levy.

D. Research and Development

CHP research and development focuses on improving performance and reliability, reducing noise and impacts on the environment, and developing smaller and more modular units. New fuels (e.g., biomass) and new prime movers (e.g., sterling engines) are also being investigated. Table 6 shows the CHP activities of the national R&D programmes. Of course, R&D is being conducted by other organisations as well.

Table 6
National R&D activities on CHP

Belgium	University and institute research, economic studies in Flanders
Denmark	Further use of natural gas, biomass fuelled CHP
Finland	Automation of DH networks and CHP systems
Germany	Demonstration projects for prototypical applications
Ireland	Demonstration projects under THERMIE programme
Japan	Fuel cells, petroleum fuelled CHP, smaller plants, environmental requirements
Switzerland	Low emission motors; design tools for small plants
United Kingdom	Lower costs, reliability, environment, new prime movers (fuel cells, stirling engine), biofuel, demonstration
United States	Advanced systems, emission reduction, high electric-to-thermal capacity

Collaborative research on District Heating and Cooling (DH&C) has been carried out under an IEA implementing agreement since 1983. The objective of this programme is to demonstrate the environmental and economic benefits of introducing DH&C and CHP schemes. It has assessed technical areas such as piping, transmission fluids, heat meters, heat production technologies, and system simulation models for DH&C and CHP. Canada, Denmark, Germany, Finland, Korea, the Netherlands, Norway, Sweden, the United Kingdom, and the United States are currently participating in this programme. The main subjects are:

- a design guide for integrating district cooling and CHP;
- advanced transmission fluids;
- piping technology, including a manual on district heating pipelines;
- supervision of district heating networks;
- efficient substations and installations;
- development of longterm cooperation with Eastern European countries; and
- information exchange.

V. CONCLUSIONS

The factors likely to shape the future potential for CHP and district heating are:

- future energy prices, both for CHP plants and for competing systems;
- the need for new electricity capacity;
- the potential transformation of electric industry structures in Member countries;
- the presence and expansion, within Member countries, of industries that are good candidates for CHP, as well as the continued electrification of the processes in some of these industries;
- technical advances in CHP, competing electric and thermal processes, and district heating; and
- possible increases in environmental taxes, and the uncertainty of their impact on CHP.

Many Member countries are anticipating significant increases in CHP use through the end of the decade. The opportunities appear to be in applications that have historically dominated CHP development — industry (including greenhouses) and district heating. Some Member countries have taken steps to increase the likelihood that these expectations will be realised. The programmes discussed in Section IV are typical of those that governments plan to continue. However, many of these policies do not seem to explicitly or logically reward those features of CHP, specifically environmental compatibility and energy efficiency, that are used to justify policy intervention in the first place. Moreover, additional analysis of the effectiveness of these policies is needed.

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